Groundwater Pollution: Myth and Reality
Implications for Rural Subdivision

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Abstract

The extensive groundwater beneath the Canterbury Plains is an important source of domestic water. In some areas the potability of groundwater is at risk from high bacteria and nitrate-nitrogen concentrations. A combination of human use on the land with associated development in a growing District such as the Waimakariri, and an unconfined aquifer has led to groundwater pollution. This pollution is a perceived potential hazard and threat to the health and safety of rural communities of North Canterbury. This thesis explores the groundwater resource at Mandeville, North Canterbury, and assesses the pollution potential. It also discusses the perceptions of the different interested parties involved with groundwater and its quality. Management options and decision-making as they relate to this perceived problem are also discussed. This thesis has recognised that if this water resource is intended for future use, untreated, then holistic management of the groundwater and land resources is necessary.

Acknowledgements

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I would also like to thank the residents of Mandeville who helped me with surveys, and pleasured in showing me around their farms. Who would guess the fun you have grovelling around the undergrowth looking for septic tanks. Thanks also to the staff at the Waimakariri District Council especially the Design Team, the staff of the Canterbury Regional Council, Environmental Science and Research and Health Link South. Thanks Hel, for the extra work you did with the surveys and data inputting.

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Thanks to my comrades on the second floor, the joviality was endless both in and out of Varsity, especially my room-mates Ned 'what is a conservation ethic?' Hardie-Boys and Kev 'have you got an hour to spend gazing at the white board?' Bishop.

A big 'cheers' goes out to the Musketeers of Peacock Palace, Nik the green thumb, Kate the spider woman, Mark the muso and Justin who kept us all sane (Hey! ....you're all stylers). Long live Friday night Jazz at Bardellies, 'Santorini' and 'Americanos'!

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CHAPTER ONE

Introduction

1.0 Preface

My grandmother would often make the trip across the Waimakariri River on her way out of Christchurch to North Canterbury. Turning West she would travel towards the Southern Alps. Here, air would be mainly clean, but on occasion the stench of fresh pig manure being spread over the paddocks would fill the car.

In only twenty minutes Gran would have reached our family's 'hobby' farm. She would always drink the water on arrival, claiming how much nicer it was in the country, cool and clean tasting. Is Gran correct, or is it just what we have always been told? In the country we are led to believe that everything is better for us, the 'clean green' image that we hear so much about. But immediately adjacent is the orchard with the frequently sprayed herbicides and pesticides, the dump which lies smouldering only a few kilometres up the road, the offal pits are full with the dead and decaying carcasses, manure is spread over hectares of farm land and every time we 'flush' there is the possibility that the remnants of last nights "meat and three vege" are entering our water supply only metres below the surface. Clean and fresh; I wonder?

Over the years Gran, as well as family and friends, have noticed the change in appearance of the plains on making that same trip out to the Ohoka area. The first sign is the appearance of new fences separating the once large paddocks. This is followed by the foundations on a newly cleared site and finally the house. Along with subdivisions scattered around the Plains there has been an increase in rural residential living. People, predominantly from Christchurch are moving to the country for that 'rural idyll', that clean living image. Is this image reality though? This is one question that this thesis endeavours to answer, with a specific focus on groundwater pollution.

This is a rather dramatic account, but how far from the truth is it? This is a matter that needs a lot of consideration if society in New Zealand is going to continue with its 'clean green' image and lifestyle. With today's environmentally aware and demanding public, and the necessity of having a potable water supply, questions are going to be asked and they must be answered.

1.1 The Issue: Groundwater Pollution

Water is the most precious resource that humans utilise from nature. It is a life support system not only for humans but "...is the living environment for a large proportion of earth's animals and plants" (Mason, 1991). Groundwater is just a part of this larger system. Both the quality and quantity of the groundwater resource are important at a global, national and local scale.

To discuss the pollution of groundwater a definition of 'pollution' is essential, as it can be interpreted and used in a variety of ways. In the literature, for example, pollution and contamination are often used synonymously. Pollution is defined variously in dictionaries as the act of making dirty, defiling, contaminating, profaning and corrupting. In the Dictionary of Life Sciences, it is defined as:

> *"the presence in the environment of significant amounts of unnatural substances or abnormally high concentrations of natural constituents at a level that causes undesirable effects, such as bronchial irritations, corrosion or ecological change"*

Connell (1981) states that pollution occurs when "substances are added to the environment causing a detrimental alteration to its physical, chemical, biological or aesthetic characteristic". Pollutants in this context are either foreign substances or natural substances discharged in excessive amounts. Pollution can therefore, be seen as a consequence of human activity as well as a natural phenomena.

A definition of pollution depends on the ideas and beliefs of an individual or a group. It is the ideas of an individual or culture that determine the aesthetic characteristics of the water quality and determines what pollution is. For example, de-oxygenated water from a forested area in the autumn is seen as a pollutant to a trout angler but to an ecologist it is a normal seasonal change in the stream.

Groundwater pollution, then, is when foreign substances or high amounts of natural substances are found in the under ground water. Most definitions are anthropocentric and concerned mainly with the effects of the pollutants on 'man'.

This thesis also takes an anthropocentric viewpoint for three reasons;

1) it is concerned with the causes/sources of potential pollution that are human induced,
2) the effects/consequences of pollution on one species in our environment (humans) is being assessed and
3) management options will relate to human activity.

An investigation of groundwater pollution is important because of the role the groundwater resource plays in the New Zealand context. Firstly the groundwater resource is in constant demand as a potable water supply, and must therefore, be protected, and secondly, it is a subject which is of legislative importance in the New Zealand context, with the newly enacted Resource Management Act 1991, with its emphasis on sustainable management. It is now a legislative requirement to understand the natural resources in a region so as that they can be managed sustainably.

1.2 Research Questions

The thesis is concerned with assessing the quality of the groundwater resource in the Mandeville area of Canterbury. This is the subject of wide debate among residents and local government staff. The Environmental Health Officers (EHOs) in the Waimakariri District Council (WDC), and the Water Quality Officers at the Canterbury Regional Council (CRC), assert that the groundwater is polluted with high concentrations of Nutrients (specifically nitrates) and bacteria, which is detrimental to the health of local residents. While the EHOs at the WDC think the water is "terrible", residents in the Waimakariri District (WD) think that the water is "excellent". There are thus many opinions, but no one knows the real truth. This research was prompted by these concerns voiced at both the regional and local level doubting the potability of the underground water resources of Canterbury.

The research is orientated around and directed towards answering four main questions:

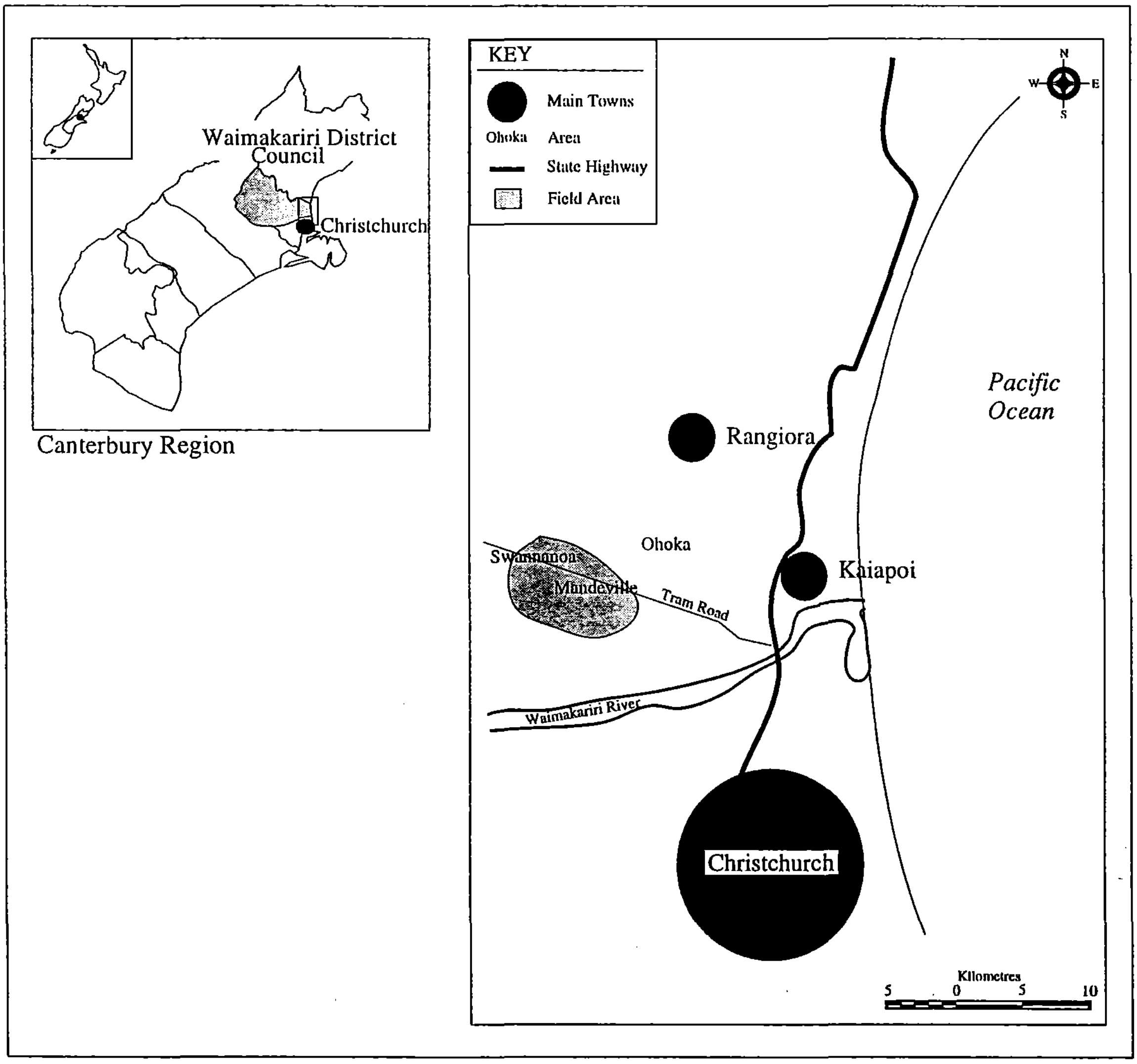
1. What is the nature of the groundwater resource, in the Mandeville area?
2. Is there a groundwater pollution problem in this area?

3. What are the perceptions of parties interested in the Mandeville groundwater resource?
4. What are the present and future management options?

1.3 An Introduction to the Field Area: Mandeville

Mandeville is an area located approximately twenty kilometres north-north-west of Christchurch (Figure 1.0).

Figure 1.0: Location of field area

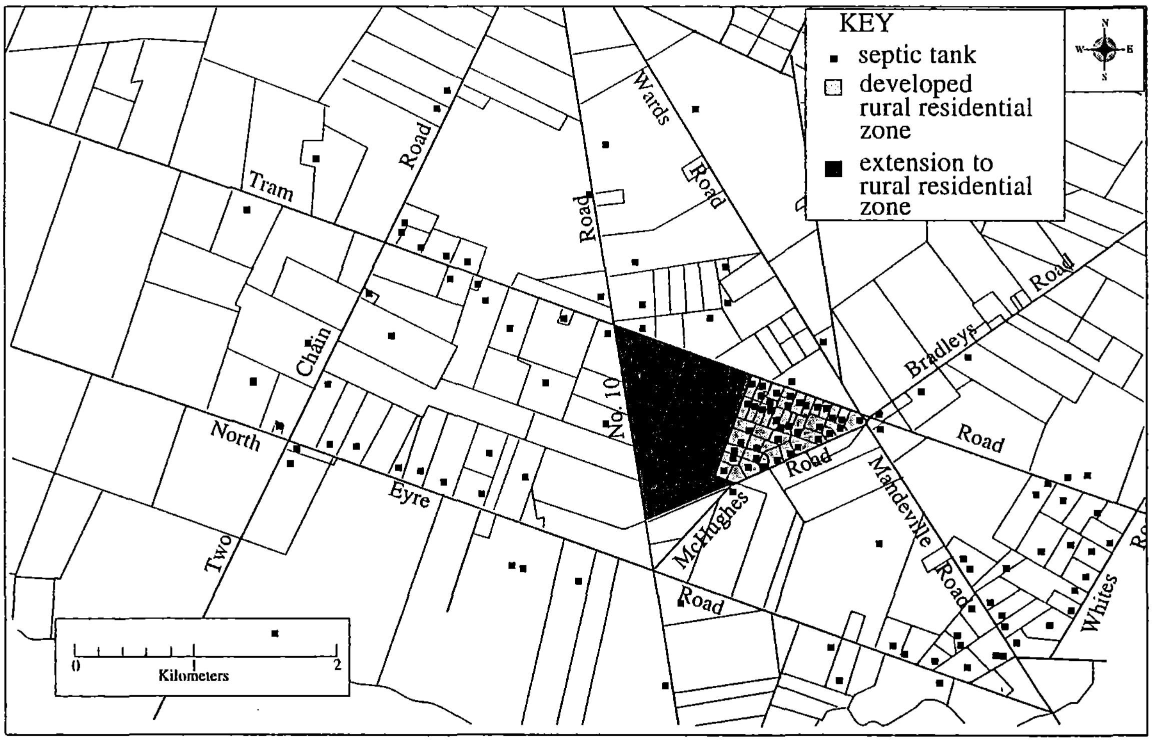


Source: Author, 1994

The field area was chosen so as to incorporate both rural and residential lifestyles. In the centre of the field area is a major rural residential subdivision whose development started in 1989. This subdivision includes 40 properties which operate on a reticulated water system, the Mandeville Water Supply

(MWS), each has an on-site septic tank. Adjacent to this, as can be seen in Figure 1.1, is land designated Rural Residential, which was changed in 1993 from its previously assigned Rural designation. A further 80 sections are proposed for development on this land. Other residential areas can be seen in this figure, including the area down North Eyre Road, Whites Road and Mandeville Road. The septic tanks denote the location of houses, which show the more concentrated areas of development.

Figure 1.1: Location of rural residential land and septic tanks in the field area, used as an indication of residential properties



Source: Author, 1994

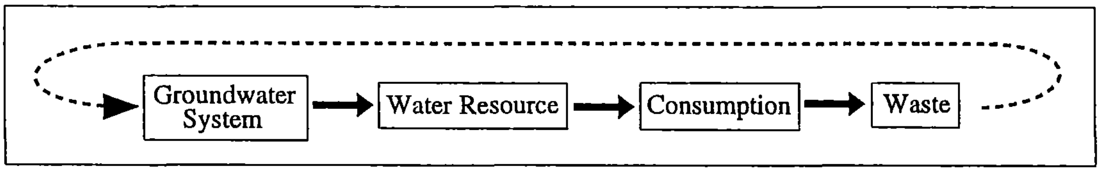
The field area consists of 38 rural residential households and 75 rural households. The contrast of lifestyles and landuses will be used to compare both the perceptions of the residents and the different potential impacts of the various landuses. The major use of the land is pastoral, in the form of sheep farming. There is also a large proportion of land used for fruit production especially apples, nectarines and grapes. It is important to know the landuse in the area so as to compare the potential impacts of landuse on the environment. Different landuses have a different impact on the land and hence the groundwater system. It is possible to explore the interactions between landuse and geology to assess water pollution potential. To assess this, knowledge of water quality in the field area is needed.

Water quality estimations in the field area are conjectural in that there is no evidence to support conclusively or dispute them. It can be said that water in the field area is similar to the Region in that it has high nitrate nitrogen concentrations and low pH levels. These both exceed the Drinking Water Standards for New Zealand 1995. Another common occurring problem is the presence of faecal coliforms, in water a bacteriological indicator contained in the water supply. These are studied because of the negative health effects associated with their presence.

Conflict between use and abuse

A significant strand in the thesis is the conflict between the use of the groundwater resource and the abuse of the same resource, often by the same people who demand it. The groundwater resource in the study area has a twofold purpose; it is important as a water supply, but it is also used as a waste disposal site. Groundwater is used for both consumptive and productive practices, as well as functioning to dilute contaminants in the environment. The consequences of this dual usage is that humans cause the hazard and suffer the consequences of having a polluted water supply. The model shown below in Figure 1.2 can be applied to this conflict to express the process of use and abuse of the groundwater resource.

Figure 1.2: Process of resource use

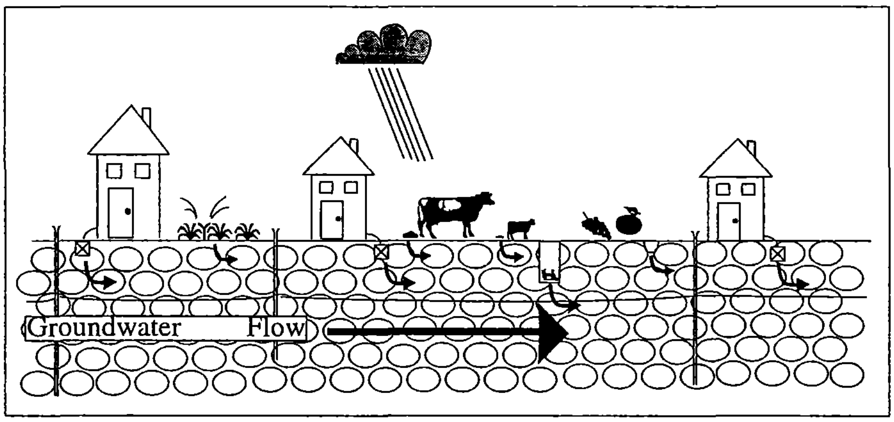


Source: Author, 1994

The water resource is extracted from the groundwater system via both private and public wells. The water is used for both domestic situations, in and around the home, for agricultural needs such as stock water, and irrigation. A result of this consumption is that byproducts or wastes are produced that recharge the groundwater system.

After re-entering the groundwater system this waste is diluted (depending on the volume of flow, and distance travelled), and may be extracted in a well downstream. According to a Technical Services Officer at the WDC there is anywhere between 5-10% of previously used water in a glass of water from the North Canterbury Plains (N.Williams, Technical Services Officer, WDC, 1994, *pers. comm.*). Using the groundwater as a potable water supply and as a disposal site "are potentially incompatible and may give rise to adverse environmental and health effects..." (Smith, 1994:1). Some of the activities mentioned above as potential pollution sources are schematically represented in Figure 1.3.

Figure 1.3: Potential Pollutants entering the Groundwater System



Source: Author, 1994

This diagram depicts a variety of potential pollutants and the location of wells. This shows that when pollutants reach the groundwater system there are no barriers preventing them being drawn into the well.

At present debate regarding the problem of groundwater pollution is in the main speculation. There is a lack of evidence regarding water quality and pollution sources in the area. The perceived problem of water quality is only a "gut feeling" (I. Davies, Programme Engineer Essential Services,WDC, *pers. comm.*), and lacks currently substantive empirical evidence to support it. The problem, however is a reality to those in the rural residential subdivision who are on a treated community scheme and are concerned with drinking their water because of the perceived excess of chlorination. It is also a reality to those residents who have installed water filters, and those who bring water in from Christchurch daily.

1.4 Methodology

In order to achieve an understanding of the political and physical processes that underly groundwater pollution, a variety of methods were used in the thesis. The use of the field area allowed this to occur. Both on-site data and secondary data were gathered. Secondary sources were used to gain a theoretical understanding and background on pollution issues and the physical processes that underly it.

Primary data was collected on the following aspects of the thesis.

(a) Geological information,
(b) Landuse,
(c) Water Quality data,
(d) Perception Survey, and
(e) Interviews.

The geological data was assessed through a comparison of well log data (log data highlights the lithology of a particular area) and secondary geological map sources such as Bowden, (1982) and Cowie *et al*, (1988). The difficulties in assessing the physical processes system are immense, especially the groundwater aspect. The aim was to understand the processes, and the geology of the area so as to assess its potential for allowing the pollution to enter and flow through the groundwater system. A landuse map was made by talking to the land-users, and by observing what was happening by driving around the field area.

Water quality data was obtained to assess the hazard potential, and was collected from a variety of sources. Reports of tests were found through Council records such as Property files. Another source of information, was a database that was established in 1994, by the WDC that records bore characteristics and water quality data of the bores that have been tested in the District. Tests of water quality were traced back to the Company that conducted the analysis, which were Telarc Companies, predominantly Environmental Science and Research (ESR). ESR stores the records of water quality tests and could provide tests that could not be located at the WDC. A source of bacteriological data was the head office of 'Tegel', who conduct bacteria tests, of the water, on all of the farms who supply them poultry. A detailed investigation of pollution detection and tracing is difficult, time consuming and expensive and was therefore not an option.

While working for the WDC, information pertinent to the thesis was collected. This involved visiting every property in the field area, locating its well(s), and assessing their characteristics. Because of the pollution threat, septic tanks were also located, and information acquired from the owner on the age and type of system on the property, other waste discharge sites had to be located also. The questions asked, and an example of a site map, can be seen in the example in Appendix 1.

A questionnaire survey was undertaken by the author (Appendix 2). The aims of the questions were to find out the perceptions of the local residents toward their water resources and how they perceive its quality. The survey is a method that allows an analysis of the ideas of the local residents. It is vital to include their opinions, as they are the ones who are directly influenced. The main problem with this was working for the WDC which may have biased some of the answers, even though it was explained that the survey was independent.

Responses were not only gathered from the local level but were also acquired at the management and scientific level. This involved interviews with a variety of members from both the regional and territorial councils, as well as scientific agencies such as Environmental Science and Research. Impressions, and perceptions of the issues were discussed to assess the various point of views.

These methods allowed a broad understanding of the issue and the conflict.

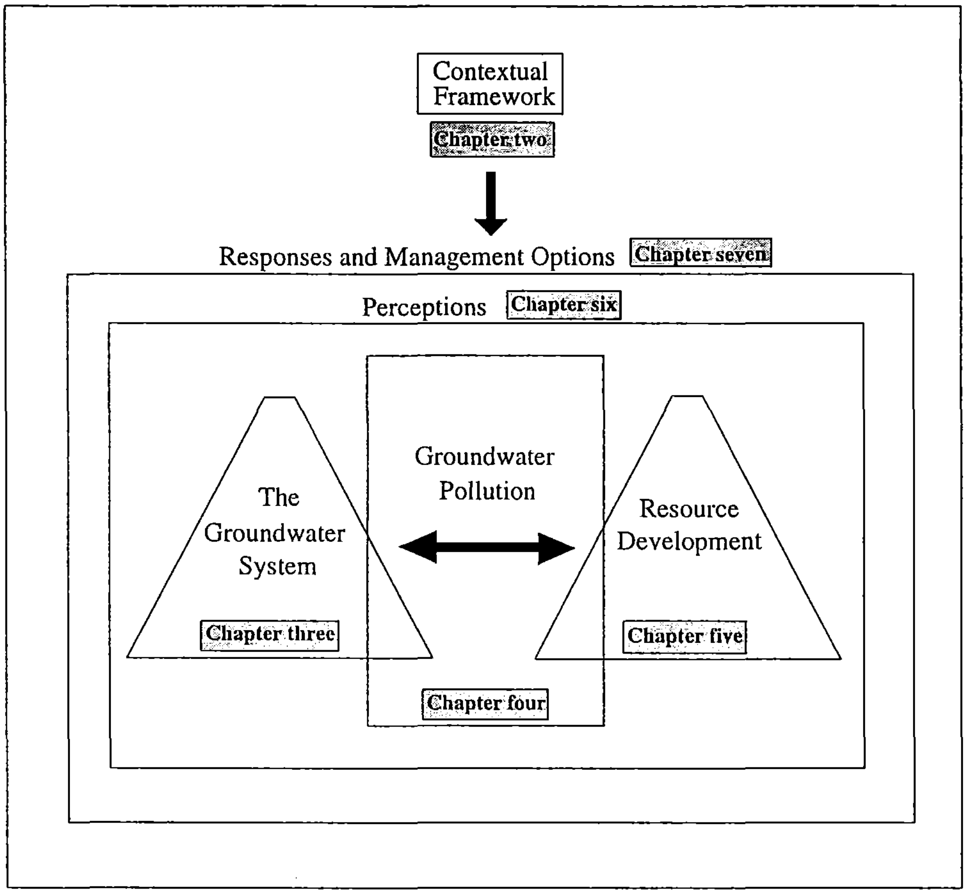
1.5 Thesis Structure

To answer the questions developed earlier in the thesis

(1. What is the nature of the groundwater resource, in the Mandeville area?
2. Is there a groundwater pollution problem in this area?
3. What are the perceptions of parties interested in the Mandeville groundwater resource?
4. What are the present and future management options?)

the thesis is divided into eight chapters, the main body of which is represented by the model shown in Figure 1.4.

Figure 1.4: Structure of the thesis



This model shows the individual components comprising the thesis as well as representing how they are interrelated. The structure shown here is a progression from the environment and society, and hazard models, which are discussed in Chapter two, 'Contextual Framework'. This material provides the wider conceptual framework necessary to support the empirical material which follows in the rest of the thesis.

Chapter Three, 'The Groundwater System' is a representation of the natural environment. It explains the nature of the groundwater system from its entry into the underground flow, through the system and finally its outcome as drinking water, irrigation to the natural springs or the ocean. This chapter also includes a review of the geology and lithology of the land. This chapter is important in understanding the complexities and difficulties of researching groundwater issues.

Chapter Four, 'Groundwater Pollution', introduces the concept of pollution and overviews aspects of water based pollution. It then discusses the groundwater conditions of Canterbury and shows how the water quality results in the field area relate to these. In Chapter Five 'Resource Development', solutions to the sources of pollution and the conditions that prevail on the Canterbury Plains are explained. This chapter is divided into two parts. The first of these discusses the land resource and how its usage over time has developed; the second examines the development of the water resource as a drinking supply.

Chapter Six, 'Perceptions' analyses the different perceptions of the interested parties. Local residents were surveyed and other interested groups were interviewed to assess how they perceived the issue of groundwater pollution. The perception box encloses the previous three chapters to illustrate that ideas on groundwater pollution are not independent of an understanding of the interaction between human use and demands on the land (chapter five) and the environment (chapter three).

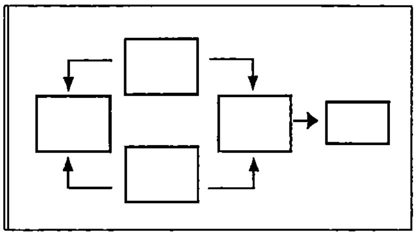
Chapter Seven, 'Management, Responses and Solutions' encompasses all of the previous chapters. This chapter relates back to the model in Figure 1.4 by looking at the existing responses to pollution at different levels. It also investigates various solutions to the problems by analysing a variety of possible solutions and management initiatives.

In Chapter Eight, the conclusion, the ideas that have been developed in the thesis are brought together and reviewed. The linkages between the findings of this study and international research on water pollution are explored, and the potential contributions of this research to the hazards literature are examined.

1.6 Summary

This chapter started with a Preface that showed what was occurring on the land through the eyes of my Grandmother, in doing so it raised issues that are central to this thesis. Groundwater pollution was discussed at the theoretical level and the five questions central to this thesis were posed. These research questions are to be investigated in Mandeville, which was introduced. The uses of the groundwater resource and how this can develop into a conflict was discussed. Methods used in the thesis are discussed, and the chapter concludes with Figure 1.4, the structure of the thesis. This structure starts with the Contextual Framework that encompasses this work which will be the topic of the following

Chapter.



CHAPTER TWO

Contextual Framework

2.0 The Environment and Society Relationship

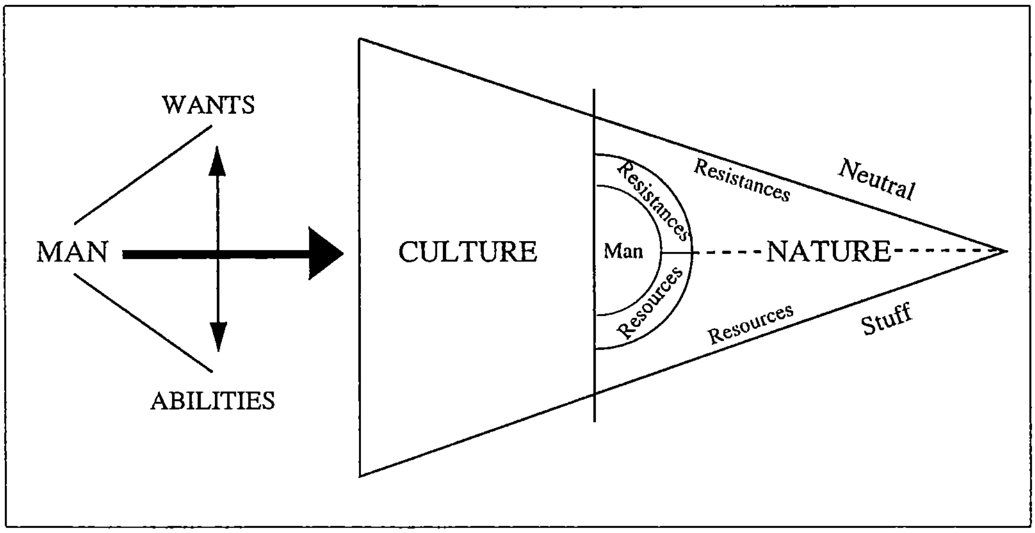
The contextual framework was introduced in Chapter One as being concerned with the relationship between environment and society and the various outcomes of this interaction. An approach adopted by Geographers and other social and physical sciences in analysing natural resources is to look at the relationship between environment and society. This approach will be developed with particular regard to groundwater pollution.

A Traditional Approach

Zimmermann (1933) provided a functional interpretation of resources. The word 'resource' "does not refer to a thing or a substance but to a function which a thing or a substance may perform or to an operation in which it may take part" (Zimmermann, 1951:7). The resource is part of a whole complex of "substances, forces, conditions, relationships, institutions, policies, etc" (Zimmermann, 1951:7), which are set in a spatial and temporal context. Mitchell's interpretation of Zimmermann states "Neither environment nor parts of the environment are resources until they are, or are considered to be capable of satisfying mankind's needs" (Mitchell, 1979:3). "Resources *are* not they *become*; they are not static but expand and contract in response to human wants and human actions" (Zimmermann, 1951:15).

An example of this is water which is seen as a valuable resource to humans because of its life supporting attributes and its productive capacity. Groundwater is "neutral stuff" part of the natural environment but because of its importance as a drinking water supply, and other production and consumption purposes it is a resource. This is especially the case if it is of high quality and quantity. Zimmermann's model depicted in Figure 2.0 shows the development of a resource through the relationship between "Man, Culture, and Nature".

Figure 2.0: Man, Culture, and Nature



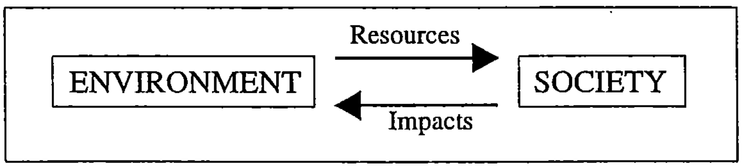
Source: Zimmermann, 1951:13

In this model, individuals (who make up a culture) with various wants and abilities appraise the environment. Culture is a "dynamic force in the creation of resources" (Zimmermann, 1951:11). Culture includes, education, training, sophistication, and relationships between individuals and groups within society. Culture has the ability to modify non-human environments, as well as affecting human attitudes and beliefs, and human relations within groups as well as between groups.

When some aspect of nature ('neutral stuff') is interpreted by society as a having use, it is therefore seen as a resource. However, nature not only provides resources to be used for production and consumption but it also has "resistances". These resistances include hazards such as flooding, tsumani or poisonous animals. These are impedances to, human development and the use of all resources.

The ideas of this model can be transferred to the model shown in Figure 2.1.

Figure 2.1: Environment and society relationship.



Source: Author, 1994.

While Zimmerman's model relates to 'Mans' use of Nature and the development of the resource concept, Figure 2.1 represents the interaction between the environment and society. Society uses the perceived 'resources' of the environment and society impacts upon the environment. The term environment relates to the natural environment and not the physical environment as it is defined by the RMA 1991. Impact is defined by the Concise Oxford Dictionary (1994), as "*an effect or influence, esp. when strong*". By this definition an impact can be either positive or adverse. In this thesis, only impacts on the environment that were determined to be negative or adverse were studied. An impact can also occur as a result of policy and decision making.

2.1 Impacts at different spatial and temporal scales

Whilst interacting with humans, the environment undergoes physical changes over time. Impact on the environment can be a result of direct interaction between human activity and the environment (such as spraying pig manure over a concentrated area of ground). Impacts occur at a variety of spatial and temporal scales. Change can be rapid and seen immediately (such as with oil spill), or slow and subtle (such as in the leaking of material from a landfill into an aquifer). Not only do rates of emission vary but so does the extent of the environment affected.

Many present environmental problems are characterised by a relatively long time lag between the period that human activity starts to give rise to the problem, and the period when society becomes significantly affected. It is at this later stage that policy is developed to cater for the problem, because it is only when the environment or humans are significantly affected that action is taken. Abuse of a groundwater system can have lasting effects on aquifers. Therefore, when planning for water resources a long term time scale should be considered. It is important to avoid problems in the long run and to realise the existing, fragile harmony between environment and society. It is important also to realise that being sustainable must mean taking into account the relationship between environment and society which takes into account socio-economic developments and the ecosystem.

The temporal scale of water pollution in groundwater systems is diverse, being dependent on the method of entry and climatic and geologic characteristics. For example the nitrate levels in groundwater will increase with rainfall because of an increase in infiltration. Therefore, there is a time lag between the nitrates being in the soil to the infiltration into the groundwater system and the time it is detected.

Spatial scales of groundwater pollution are even more diverse. Because of the nature of groundwater systems, sourcing pollution is very difficult without a thorough knowledge of the flow. Being able to detect nitrate levels in a well is simple, but to find the source can be very difficult. The nitrates may have accumulated over space and time, travelling for kilometres before being detected. The Canterbury Region has a history of high nitrates, therefore the field area is a local example of a region wide problem. Contrary to this is the case of bacteriological substances being found in wells. The source is usually local because of known rapid die-off rates of bacteria, yet under certain conditions and a preferred flow, bacteria can travel up to 1 kilometre before dying.

Human activity creates direct impact on the environment, but this activity is often the result of policy and legislation, so that current legislation and plans can influence the extent to which activities will impact on the environment. However, plans may not stop activities that are unsound, that would occur regardless, owing to blatant disregard of the environment and of environmental policy. While illegal activities continue, it is difficult to devise a total picture. Change in environmental policies and legislation have occurred from the global to local scale. While awareness of impacts on our environment grows, policy and laws develop at both the international and national level. Policy and environmental events are important in tracing what has been politically and ecologically significant issues.

A spatially renowned 'hot topic'

The importance of water is shown in countries such as "Egypt, Jordan, Israel and Syria (where they) are rapidly reaching the point where all available water, above and below the ground, is fully committed. The situation is regarded as explosive" (Young, 1991:15). Water resources play a critical part in the politics of the Middle East. Many experts forecast that the next Middle East war will be about water (JRO Topic Map, 1994:15).

Groundwater has always been considered a readily available, high quality source of water for potable, agricultural and industrial use. However, with increasing demands, major changes in landuse and the vast increase in types of industry, agriculture and domestic effluent entering the hydrologic cycle, the stresses on groundwater resources are growing rapidly. An example from Sri Lanka by Das Gupta (1992), states that 75% of wells tested in that country in the 1980s were bacteriologically polluted. He went on to comment "the extensive use of fertilises, insecticides and pesticides coupled with over irrigating contributed to the contamination of shallow groundwater resources in many areas" (Das Gupta, 1992:13). This example in Sri Lanka shows not only the state of the water quality but also the link between the land use and the water system.

Are these international cases an example of a world wide trend of deteriorating water supplies, a case of people being more aware of our natural environment and demanding better environmental standards overall, or a combination of both? A response that has occurred in light of the dearth of information and in response to growing water concerns is the development of International Organisations, which are discussed below.

The Development of International Organisations

The problems of resource scarcity and deterioration were becoming a global issue that led to conferences and commissions being set up at the international level.

In 1958 the World Health Organisation (WHO), established International Standards for Drinking Water, "Supplies of drinking water should not only be safe and free from dangers to health, but should also be as aesthetically pleasing as possible" (WHO, 1958:9). These standards were updated and Drinking Water Standards for NZ 1995 (Ministry of Health, 1995), are based on the WHO's 1993 Guidelines. In 1966 the United Nations Education, Scientific and Cultural Organisation (UNESCO) adopted a resolution that recognised that environmental problems were an object of international policy. The *Biosphere Conference* in Paris in 1968 decided that changes in the environment had reached a critical threshold. From 1968 on, the "concept of human interdependence with the biosphere was implicit, even when not explicitly stated, in declarations of international environmental policy" (Grundy, 1993:17).

The UN Conference on the Human Environment held in Stockholm in 1972, was the time when "'environment' arrived on the international agenda" (Sachs, 1991:252). Water was among the "global issues" discussed at the conference. "The cognitive furniture for this shift was provided by a particular school of thought that had gained prominence in interpreting the significance of pollution and non-natural disasters" (Sachs, 1991:252). The Conference epigram, *'Only One Earth'*, symbolised a change in human perceptions that would become a new factor in the development of human ethics, and in the evaluation of policies relating to the environment (Grundy, 1993:18).

The International Union for Conservation of Nature and Natural Resources (IUCN), in 1980 developed a *"World Conservation Strategy"* a further step towards an integration of environment and development concerns and introduced intergenerational responsibilities. In its foreword it stated: "Human beings in their quest for economic development...must come to terms with the reality of resource limitations and the carrying capacity of ecosystems, and must take account of the needs of future generations" (IUCN, 1980). Yet there were still developing nations that were suffering poverty and not able to deal with the present generations. There was a UN effort to defeat the scourge of dirty drinking water in the Third World, 1981-1990 was labelled *Decade of Drinking Water*. But it was not only the Developing Countries that suffered problems, it was "estimated that half of the population in the Organisation of Economic Cooperation and Development (OECD), countries can only obtain clean water from treatment plants because rivers, lakes and groundwater are polluted by sewage, fertiliser, pesticides and industrial chemicals" (JRO Topic Map 1994:12).

In 1987 under the chairwoman of the World Commission on Environment and Development, Gro Harlem Brundtland, there was the "marriage between craving for development and concern for the environment" (Sachs, 1991:252). The Brundtland report titled *"Our Common Future"* stressed the inseparability of environment and development and introduced the world to the term "sustainable development". It was realised that there could be no growth and development, if there were no long term availability of natural resources.

The issues are still being debated as late as 1992 in Rio de Janeiro at the *"Earth Summit"*. Rio saw an intensifying global interest in the planet's future, as 35,000 people attended. Indicators still showed a continuing wholesale deterioration in the earth's physical condition (Brown, 1993:4). The key issues debated were still the rate of global consumption. It was also made aware that the "finiteness of the world's resources is related more to the planet's capacity to absorb waste, toxins, and such things...than to a shortage of the basic natural resources themselves" (Strong *in* Kopp, 1992:19). Maurice Strong is a member of the United Nations Conference on Environment and Development (UNCED), who developed the *'Earth Charter'*. The Earth Summit saw the importance of uniting the First and Third Worlds, in a common aim. There was recognition that water pollution is an especially important issue in the developing countries, where water related diseases such as cholera, malaria, schistosomiasis, diarrhoea and giardia kill and debilitate millions of people annually.

Is it simply rhetoric at the international level, and is it this rhetoric, that is filtering down to the national and local levels? New Zealand's policy and legislation entails similar jargon as used at the international scale, and has developed over time in line with the international and local demands. Has there been a real change in the ideals and perceptions of the politicians, bureaucrats and the general public, and do changes in legislation affect the environment at the ground level?

2.2 National Legislation: A change in the way we view resources?

Global literature and concerns, come from the issues that an individual nation faces. New Zealand must face its water issues in both a quality and quantity capacity. The management of a groundwater resource and its protection from contamination is of increasing concern for regional authorities particularly in the South Island where the groundwater, which is the main supply of water to both public and private wells, lies within a shallow unconfined aquifer. Lack of such protection exposed itself in North Otago in the early part of 1990 where a Giardia outbreak contaminated the Kakanui River and water scheme, affecting predominantly males between the ages of 31-40 (Stroud *et al*, 1993), and again in 1995. Another example of unsustainable management is the recent and continuing problem of Auckland's water supply. Also in South Auckland is the case of the Kingseat subdivision with a nitrate polluted water supply from Pukekohe.

Groundwater provides an example of how we deal with our natural resources. There is an obvious shift towards a more integrated approach in managing the natural resources in New Zealand. Human needs must be met, but in conjunction with water's economic, ecological and political characteristics. This entails developing a wholly new relationship with water. Historically we have managed water with a frontier philosophy, manipulating physical systems to whatever degree engineering know-how would permit; building canals, dams and diverting rivers.

Water Legislation in New Zealand

Early legislation was development orientated, such as the Land Drainage Act 1908. Matters relating to water were incorporated into subsequent legislation, notably the Counties Act 1920 and the Public Works Act 1928. The 1930s with an abundance of land clearance, saw erosion become a major problem. It was then realised that water and land would have to be incorporated into the same legislation. This concept developed in 1941 in the form of the Soil Conservation and Rivers Control Act. The abundance of water in New Zealand led to the assumption that pollution was not a problem and that effluent could be readily diluted and washed away (Ward and Scarf, 1993:65). Groundwater was ignored, and there was limited knowledge of the interaction between what occurred on the land and its effect on the groundwater.

The Water and Soil Conservation Act 1967 was comprehensive and enabled law to "establish a regulatory structure for the administration and control of water resources through combined catchment boards and regional water boards" (Ward and Scarf, 1993:65). It was the Crown's responsibility to control discharges, and water rights had to be sought through the Crown. The Act was implemented at the national level through the National Water and Soil Conservation Authority (NWASCA). This took a more integrated approach to managing the resources, yet it was hard to change the ideas of those who implemented the Act because of the change in focus to water resource management (Ward and Scarf, 1993:65). With conflicts arising through multiple use of resources, it was realised that there needed to be an alternative solution. The addition of management plans in the 1970s were welcomed but with no legal backing, they were not a strong influence in managing the resources. The 1981 amendment to the Water and Soil Conservation Act 1967 provided conservation orders and notices. This allowed applications to be made by interested parties to preserve the natural state, or scenic characteristics of water ways. This gave the public increased access to the planning system.

Political conflict between local authorities (who dealt with land use planning), and regional authorities (concerned with catchment and water resources), meant an integrated management regime was not implemented effectively. During the 1980s comprehensive restructuring took place throughout all sectors of the New Zealand economy. The environment was included in this change.

Structural Change in New Zealand in the 1980s and 1990s

Restructuring occurred at all levels of government and through all sectors of the state. There was a lot of change, "especially the role of the state in respect of environmental administration, the provision of commercial activities and the management of the core public services" (Britton *et al* 1992:165). The state has been predominant in New Zealand's economic and social life. Restructuring changed this by corporatising, departmentalising and privatising. It was the emergence of neo-conservative ideals in which the state is removed from resource allocation and the emphasis is shifted to the market and individuals.

In conjunction with this, was the Local Government Amendment Act No.3 1988, which implemented reform of local government and redrew the local government map. A new tier of Regional Councils was set up responsible for natural and physical resources. Regional boundaries now represent the water catchments. In line with the national market-led ideologies local governments no longer 'plan' for a District, but administer an area, with their emphasis still on land use.

This local government restructuring was needed to administer the new RMA 1991 which was a part of the Environmental administration and law reform. An alliance was needed between the conservation and development perspectives, and it came in the form of the RMA 1991, under the new Ministry for the Environment. Environmental Law Reform was attributable to an increase in environmental awareness that was occurring in New Zealand. "The environment was becoming increasingly politicised" (Britton, *et al* 1992:188). Significant national development programmes, the erosion of native forests and water resource scarcity and pollution were of concern to a growing number of people. But there was a dual reason for the reform which included the Treasury, and the unnecessary use of state resources for limited returns. Government Departments such as the New Zealand Forestry Service had conflicting roles, therefore, Treasury agreed that a separation of the administration, development and conservation functions should be carried out to achieve better accountability (Britton *et al* 1992:188).

The Resource Management Act 1991

The RMA 1991 plays its part in the new ideology. "It is primarily a law to control externalities. It incorporates greater allowance for the use of economic instruments...reflecting the application of the market to the environment in the interests of more effective and efficient management solutions" (Britton *et al* 1992:195). The Act's key concept 'sustainable management', was strongly advocated in the Brundtland report *Our Common Future.* The focus of the Act is on regulating the impacts of human activities on the environment and not on human activities *per se*. For example, under the Act, it is not an actual subdivision that is regulated (but it can be under a District Plan), but the effect of subdivision on the environment, this includes the groundwater system.

Water is a classic example of a resource that must be sustainably managed. The most significant effect of the new RMA91 on water resource management is s5, the section that highlights the sole purpose of the Act. The purpose of this Act is to promote the sustainable management of natural and physical resources. Sustainability was strongly advocated in the Brundtland report *Our Common Future.* Sustainable management in the RMA means;

> *"managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while-*
>
> *(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonable foreseeable needs of future generations; and*
>
> *(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*
>
> *(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment".*

This definition comprises two elements "described as the management function and the ecological function" (Fisher, 1991:28). Paragraphs (a), (b) and (c) contain the ecological function. It is up to the courts to decide whether the 'while' will subordinate, be superior to or coordinate the management function in the earlier clause.

Paragraph (a) pertains to water as a natural resource that must be sustained to meet the foreseeable needs of future generations. If an anthropocentric viewpoint is taken, polluting groundwater this is not regarding the needs of the future generations.

Water is a life-supporting component of the natural and physical environment that must be safeguarded. Must it be safeguarded for its own sake, because of its role in the natural environment, or to enable people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety? District Councils take an anthropocentric viewpoint, and are concerned with the later argument.

Sustaining water quality is important for the communities health and safety. If development or landuse has adverse effects on the environment then under the RMA91 this must be avoided, remedied, or mitigated. Bearing in mind that the definition of effects includes;

> *"(a) Any positive or adverse effect;*
> *(b) Any temporary or permanent effect;*
> *(c) Any past, present , or future effect; and*
> *(d) Any cumulative effect which arises over time or in combination with other effects- regardless of the scale, intensity, duration, or frequency of the effect and also includes*
> *(e) Any potential effect of high probability; and*
> *(f) Any potential effect of low probability which has a high potential impact."*

In relation to discharge permits or hazardous substances, the concept of cumulative or combined effects is very important. This is relevant in the thesis with regard to the effect of septic tank discharge and other potential pollutants in the natural environment. This definition makes a developer or user of a natural or physical resource, be aware of consequences of their actions, and always look for alternatives.

By using a very broad definition of environment to include both the natural and physical surroundings this incorporates buildings and houses. The Act confers an obligation to manage the "physical resources...which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety..." s5(2). For people wanting to live in a rural environment this section of the Act is applicable as they perceive country living as being part of their social wellbeing and contributing to their health. Yet in some situations the reality is contrary to this. Some areas of North Canterbury are isolated, and lack high quality essential services which is in fact detrimental to the social and economic wellbeing and the health and safety of people and communities.

This Act must be looked at in relation to other relevant legislation such as the Health Act 1956 and Building Act 1991, because within these Acts are the obligations of the various authorities that must administer the legislation, in relation to the health and safety of communities. Interpretation of the legislation must be decided in the Courts and at the operational level. The law is only as effective as those who administer it.

Economic and political gains and the desires of humans are seen as being more important than the needs of the environment as a whole. It is still an anthropocentric philosophy that prevails in the minds of the politicians, the bureaucracy and the majority of the public. "The predominant attitude to water management, at least in the developed countries, has been technocratic in nature" (Postel, 19923). As a society in New Zealand we are interacting with the environment to more of an extent, and through this interaction are continuing to impact on the environment. A way to view this interaction is to look at a specific outcome of the relationship between groundwater and human occupation of land through a look at hazard literature.

2.3 Adopting Hazard literature

Hazard theory has derived from the environment and society relationship literature, and therefore has many parallels within this context. Hazard literature deals with all the issues that are apparent in the thesis, as it incorporates human activities on the land, resources, the physical processes system, the hazard and responses. Just as the resource is a product of human abilities and wants, the hazard is a product of humans interaction with nature.

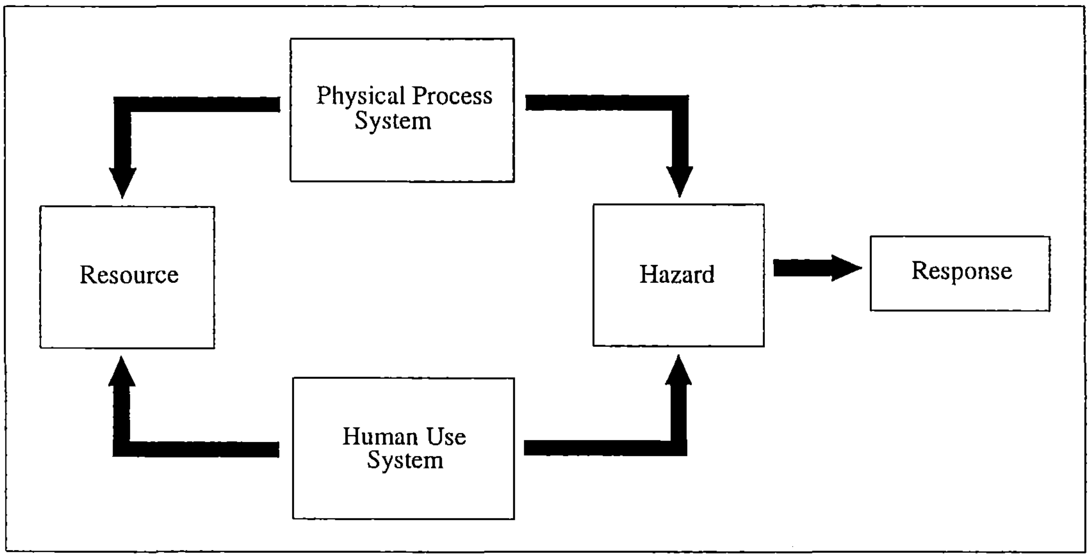
A 'resource' as mentioned in the earlier sections is a part of nature that has been defined by humans because of its assigned value. "It is people who transform the environment into resources and hazards, by using natural features for economic, social and aesthetic purposes" (Burton, Kates and White,1978:20). Burton, Kates and White (1978:20), have called hazards "negative resources" while Zimmerman (1933) refers to them as 'resistances'. These two terms have negative connotations as hazards are seen as being detrimental to human wellbeing or survival, the part that they play in nature is ignored, for example, a flood is necessary to build a delta and provide fertile soils, and an avalanche is simply the removal of excess snow.

It is because of the presence of humans and the human use system that natural events in the environment are regarded as hazards. A 'natural' hazard can be defined as "risk encountered in occupying a place subject to flood, lightning, mass movement and avalanche etc" (Burton, Kates and White, 1978). Groundwater pollution cannot be so easily slotted into the natural hazard definitions. Many of the pollutants in the groundwater are naturally occurring yet it is because of farming practices (which is a human use), that levels of bacteria and nutrients for example, have increased.

Many authors including White (1974), Burton, Kates and White (1978), Speden and Crozier (1984) and Bryant (1991) have coined the phrase 'natural hazards' to talk about the extremities in nature, the situation which is catastrophic and abnormal. Society has always suffered natural hazards but the prevailing scientific view of the problems is a recent one (Hewitt, 1983). Scientific studies have isolated extreme events, so they are not regarded as a part of the natural environment, they are seen as abnormal, something to be protected from. A hazard here is described as a "...potential situation which will cause damage to property, people and the *environment*" (Speden and Crozier, 1984, emphasis added). This is the 'environment' as defined by humans needs and desires. It is a dominant view that the disaster or hazard is attributable to nature, and society can affect disaster, through public policy, backed by geophysical knowledge, technical know-how, and management decision making (Hewitt, 1983).

What emerges according to Hewitt (1983:10) is that hazards are not viewed as integral parts of the spectrum of the environment and society relationship, but as a diverse adaptive problem, an issue that must be looked at and studied separately. The problem is that the hazard has been too removed from nature. The application of hazard theory can be seen in Figure 2.2.

Figure 2.2: Hazard Model

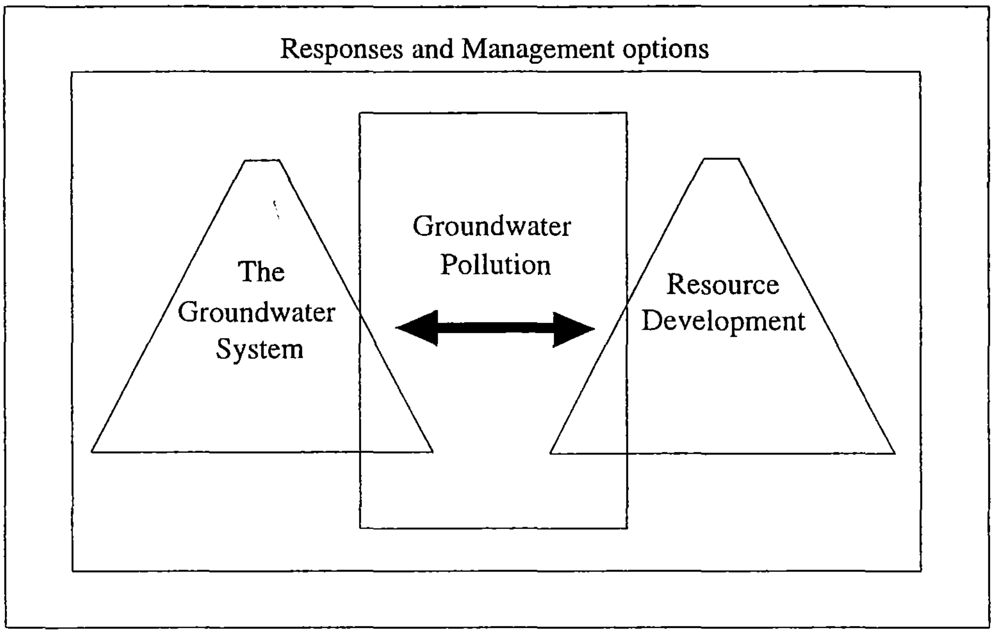


After: White, 1974

The model shows how the natural events system and the human use system function independently of each other. Interaction of the two creates resources. It also creates hazards or negative resources. The response relates to the various responses that individuals or groups make as a consequence of a hazard. This is explored further in chapter seven.

The model developed as an alternative to this in order to recognise the more interrelative nature of the process is given below as Figure 2.3. This shows that the interaction between the groundwater system and land, through resource development has resulted in the groundwater pollution. 'Responses and Management Options' should be considered in all parts of the system therefore this section is encircling the interacting systems.

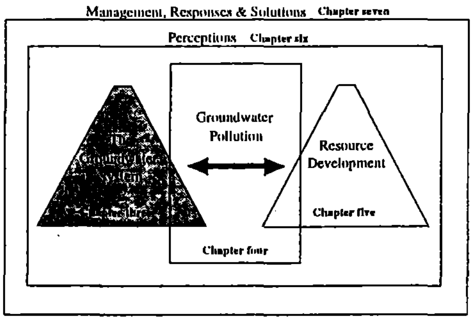
Figure 2.3: Development of hazard groundwater pollution



Source, Author, 1994

2.4 Summary

This Chapter has put groundwater pollution in a context, by showing how groundwater pollution is a part of the 'Environment and Society' relationship. It has also shown why the issue is important at a variety of spatial and temporal contexts. Water quality issues that are important at Mandeville at the local scale are also important at the regional, national and international scale. The development of legislation over time has shown how the environment has become more important. Groundwater pollution can be seen as a hazard and therefore the adoption of hazard literature is significant. This emphasises the interaction between the human use systems and the physical processes systems. "Any study of environmental hazards will necessarily involve an examination of the complex interactions between physical and human systems, since no hazard can exist unless it is perceived an in turn provokes a human response" (Whittow, 1980,19). Chapter three discusses the groundwater system which describes the nature of the physical processes system.



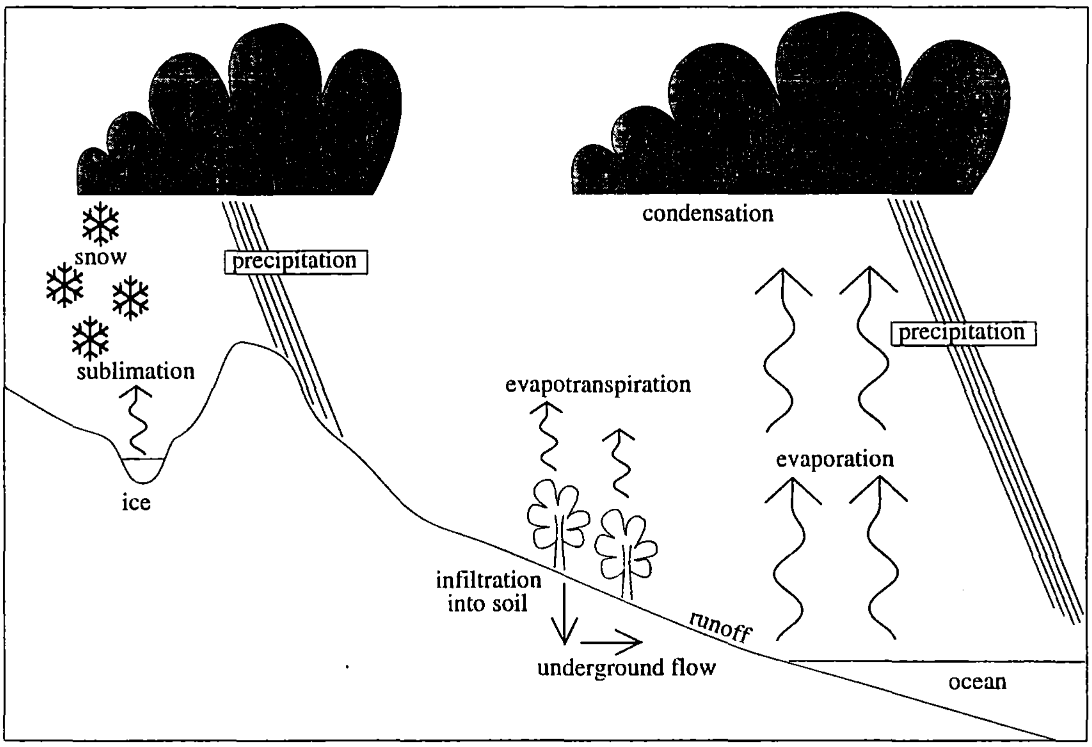
CHAPTER THREE

The Physical Environment

3.0 Groundwater and the Broader Picture

To understand groundwater pollution it is important to describe the physical environment. There must be an appreciation of groundwater and its associated environment. "Groundwater is the great 'unseen' element of the hydrologic cycle. Because it is out of sight it is frequently out of mind" (Konikow, 1985). The groundwater regime is a dynamic system in which water is continuously in motion. In a typical groundwater system this movement occurs through extensive heterogeneous material via an interconnected geological framework. A schematic representation of groundwater and its relationship to the rest of the hydrologic system can be seen in Figure 3.0

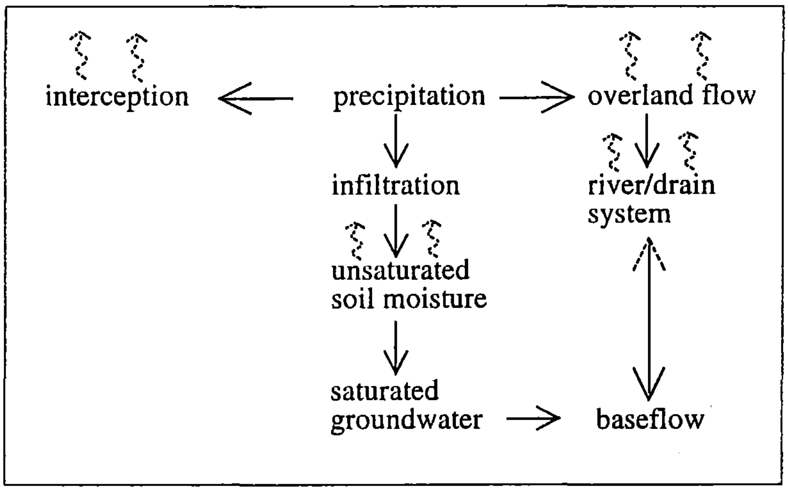
Figure 3.0: The Hydrologic cycle



Source: Author, 1994

Of the moisture in the atmosphere, some collects together and falls as precipitation. Some of this evaporates before it hits the surface while the precipitation that reaches the earth is evaporated, filtered into the soil, and some may run off overland to evaporate or filter elsewhere, or enter a stream system. Transpiration takes place when water is taken up by the root system and is expelled by the leaves. It is the water that has entered the ground that is of focus in this thesis. Out of the water entering the ground reservoirs, some will rise in the form of springs, or move downstream until it reaches a lake or the ocean where it is again evaporated. This is a generalised model of the water system, a part of this cycle is shown in the model Figure 3.1 which concentrates on the water flow that reaches the groundwater system.

Figure 3.1: Recharge and discharge from the groundwater flow



Source: Author, 1994

It is through the processes of infiltration, and the contribution of river and drainage systems to the baseflow where pollution enters the system. The saturated groundwater or base flow can be defined as "a subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated" (Canter *et al*, 1988:1). Potential for groundwater recharge in the field area depends on natural patterns of annual precipitation. The river system of the Waimakariri River recharges the baseflow of the Canterbury aquifers that provides Christchurch with its water supply.

3.1 Hydrogeology

The Medium

The geology in which the groundwater is found is important, as characteristics such as water availability, movement and quality depend on it. It is therefore important to be aware of the geologic and hydraulic properties of an aquifer in order to "facilitate a basic understanding of potential contaminant transport through the aquifer system and to see the degree of influence from landuse" (Hughes, 1989:24).

The field area displays recent soils which are generally free draining with a weakly developed profile, horizon and structure. The main constituents of soil are organic matter, water, air and mineral particles. Mineral particles are divided on the basis of size into sand, silt and clay. "Sand enhances the drainage, while silt and clay facilitate the movement and retention of molecular water in the soil" (Marsh and Dozier, 1981:212). In the soil profile, clay attracts positive charged ions called cations, such as potassium, sodium, calcium and magnesium which are important nutrients for plants. The field area has little clay and therefore has low nutrient reserves. The soil is also coarse, and therefore tends to be more acidic and there are fewer opportunities for cations to be absorbed. The low nutrient reserves reflects the landuse in the area, which is predominantly pastoral farming. The shallow, stony, freedraing soils are similar to 60% of the soils on the Plains.

The presence of water and air in subsurface soils is attributable to the fact that the subsurface is a "porous medium". Well sorted sedimentary deposit has high porosity while poorly sorted sedimentary deposit has a low porosity. The porosity of the soil is simply the volume of the soil that is available for storage of water. It is beneficial to know the effective porosity which is the percentage of interconnected pore spaces. Effective porosity implies some form of connectivity through the medium and is closely related to permeability.

The permeability of a porous medium describes the ease with which a fluid will pass through it and indicates its capacity to transmit water. Alluvial gravels are known to be permeable and thus tend to yield high amounts of water. Variation in the permeability can be significant over distances of a few meters in the vertical direction and over tens of meters in the horizontal direction. This small scale variability significantly affects the performance of individual wells, whose yield is influenced by the strata immediately surrounding the well screen. The well logs illustrated in Appendix 4 confirms this variability. Appendix 5 shows the location of these wells in the field area.

The specific yield of soil or rock is the ratio of the volume of water which the soil or rock, after being saturated, will yield by gravity to the volume of rock or soil. In the natural environment specific yield is generally observed as the change that occurs in the amount of water in storage per unit area of unconfined aquifer as the result of a unit change in head (American Society of Civil Engineers, 1987:16). Yield and specific capacity are an assessment of performance of an aquifer. An aquifer with a high specific capacity, has a small drawdown and is therefore, a high yielding area. A yield value greater than 10 l/s indicates a viable source for irrigation, whereas those zones of less than 5 l/s have limited potential for groundwater abstraction. Table 3.0 shows that the field area is located in an area that is high yielding.

Table 3.0: Groundwater Availability in the field area

	Depth to water bearing layer (meters)	yield		specific capacity (l/sec/m drawdown)	water level (meters)	
		l/s	g/min		high	low
Swanannoa	11-25 30-35	5-28 7.5-11	65-375 100-150	0.5-8 2	0.5 10	16 >15
Mandeville North	8-15 18-24	19-30 7-17	250-400 90-230	5 1-2	0.5 1	10 10
Eyreton	4-15 22	10-45 up to 27	135-600 up to 360	5-25 4	0.5 -	5 -

After: Cowie, et al 1988:168-9

In order for groundwater to be used as a water supply the formations must have adequate permeability to transmit and yield water. A geological formation having these characteristics is called an aquifer.

Aquifers

There are two types of aquifers; confined and unconfined. Confined aquifers, or artesian aquifers are bounded on the top and bottom by layers of relatively impermeable material called aquitards or confining layers. Water is under greater than atmospheric pressure and recharge is not uniform but takes place over only a portion of the aquifer. Unconfined aquifers contain water under atmospheric pressure. The upper surface of the water may rise and fall according to the volume of water stored, which is dependent upon natural recharge. This aquifer has no clay or impermeable layer separating it from above. It is this later aquifer that is present over most of the inland Canterbury Plains.

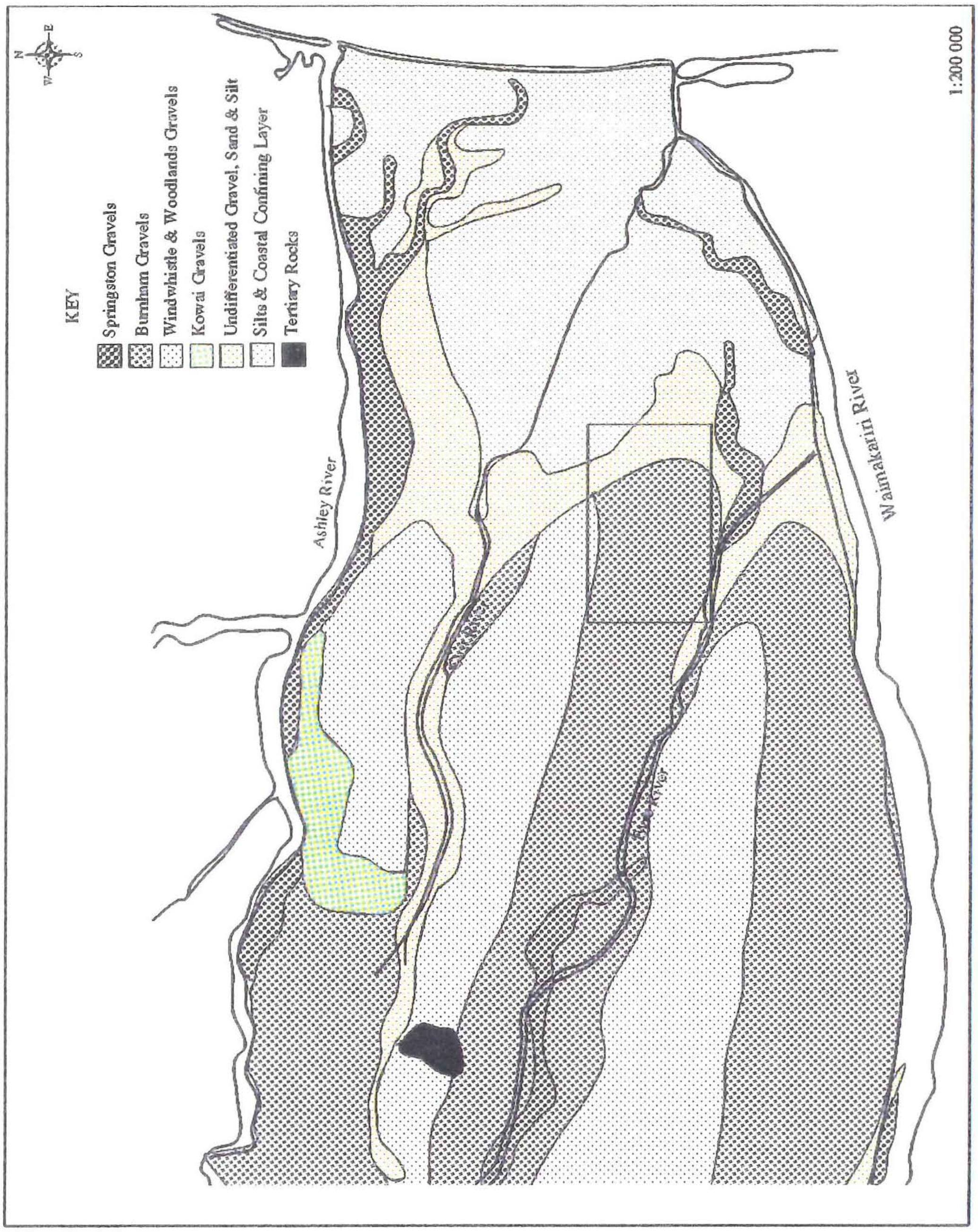
3.2 Development of the Canterbury Aquifers

The Geology of Canterbury

The Canterbury Plains extend over an area in excess of 8000 km^2. The basement rocks in the region are underlain by complexly faulted and folded greywacke and argillite. This basement is underlain by Late Cretaceous and Tertiary marine sediment. The superficial deposits an the Plains comprise a thick succession of fluvioglacial gravel fans built during the later part of the Quaternary by eastward flowing rivers from the Southern Alps. Fractures and jointing in the rocks during the two major Orogenies facilitated mechanical weathering during the rigorous fluctuating climates. (Wilson, 1985). Three major periods of glaciation have been recognised, each period has been characterised by glacial erosion in the major river valleys and the aggradation of large outwash gravel fans close to the point of emergence of each river from the foothills. Figure 3.2 illustrates the surface geology of the Waimakariri- Ashley Plain.

The geology of Mandeville is set within this context as Bowden (1982) illustrates. The field area is underlain by the Woodlands Formation which comprises fluvioglacial outwash gravels, sand, silt and clay, from the Waimakariri, which is typically poorly sorted. Over this Formation lies the Windwhistle Formation from the Eyre River and above that the Burnham Formation almost entirely made up of greywacke pebbles. Because of rapid accumulation due to the immense amounts of water in the rivers this gravel is poorly sorted and coarse.

Figure 3.2: Surface Geology of the Waimakariri-Ashley Plain.



After: Cowie et al, 1988

The most Eastern section of the field area in Ohoka has an extra layer known as the Springston Formation. This Formation differs in that it is made up of undifferentiated alluvial gravel, sand and silt. During warm interglacial periods erosion in the higher altitudes declined as vegetation cover increased. Starved of sediment, rivers downcut and entrenched and material was reworked and redeposited further down the coastal plain as this cleaner, better sorted gravel.

3.3 Geological Influence on Groundwater Flow.

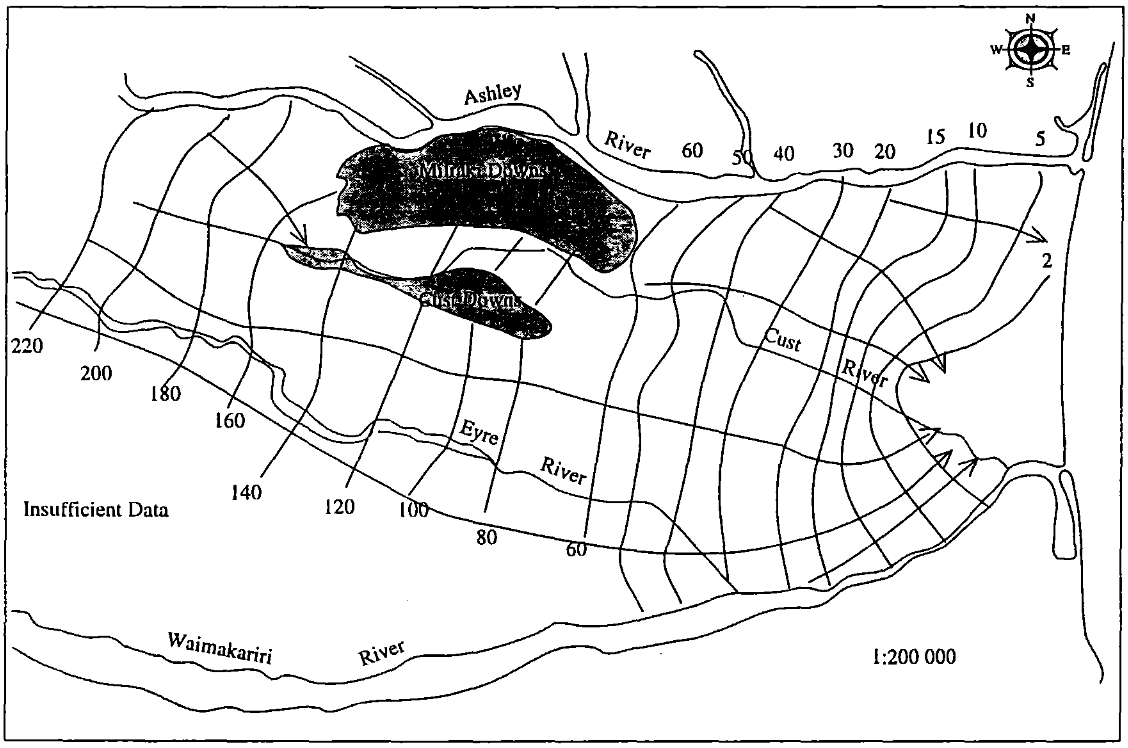
Knowing the complexities of the geology it is easy to see why there is conjecture over establishing rules and assessing the groundwater resource in the area. General comments however can be made about the geology in the area. The groundwater resource is contained within these glacial outwash and post-glacial alluvium plains. It is the geology of the area that determines the routes and rates of groundwater flow. With the meandering of the river channels over time across the Plains the material has been reworked. Like the preferred channel that a river will take, groundwater will move similarly moving through more permeable material. The well sorted gravels that have been reworked by the rivers are highly permeable therefore the flow will be faster. The reworked Springston gravels for example are highly permeable, as is the region along the Eyre River.

The older and more deeply buried gravels have a greater extent of compaction, weathering and cementation, this generally decreases permeability and can explain why water cannot be reached at useable quantities at depth. The Burnham Formation is a shallow deposit. Wells in this area are between 2-30 meters deep. It is possible that older buried permeable Eyre River channels exist at depth (Bowden, 1982:84).

Influent seepage occurs generally from the rivers into their own sequence of fans. This is evident when the Eyre River, which only flows on the surface for part of its length is in flood, and the adjacent water table rises. Observations by the author have been made in the field area when the Whites Road shingle pit approximately 3 kilometers north of the old Eyre River bed rises approximately 4 meters. It is also evident when water in Sefton and Loburn which are approximately 14 kilometers north of Ohoka is traced to the Waimakariri River. This groundwater travels in permeable layers under the Ashley River.

Knowing groundwater flow patterns is a key to interpreting the pattern of contaminant migration (Domenico and Schwartz, 1990). Contaminants such as viruses, organic compounds, bacteria or chemicals follow the flow of the groundwater independently or attached to some form of particle. Therefore understanding flow parameters is important. The general flow patterns in the plains area is shown below in Figure 3.3. Direction of flow is predominantly west to east from the Alps to the ocean (these are flows in the upper aquifers only). To understand flow patterns fully, would require an extensive on-going study, because as a river changes course to choose the path of least resistance so to does the groundwater. As a river meanders so to does the groundwater, with paths running laterally to the main directional flow.

Figure 3.3 Generalised flow patterns on the Waimakariri-Ashley Plains



Source: Cowie, et al 1988

Velocity of flow is also important because it can be used as an estimation of how far a potential contaminant will move in the groundwater system. If direction and velocity are known, a contaminant can be traced. Water movement is governed by estimating hydraulic principles. Because groundwater moves slowly a difference in water table level or hydraulic head is built up and maintained between areas of high elevation and those of low elevation. The velocity of laminar flow follows Darcy's Law, which states that velocity varies directly with the hydraulic gradient or

$$v = k\frac{\Delta h}{l}$$

where:

v = velocity

Δh = difference in head between two points in the path of movement

l = distance along the path of movement

k = permeability

for water moving in the zone of saturation the factor the change in h/l becomes the hydraulic gradient.

Aquifer Recharge

Most of the groundwater of Canterbury is river recharged but some areas of significant local precipitation contribute to recharge. Recharge is clearly identified by ^{18}Oxygen and chemical concentrations. (Taylor, *et al* 1989) ^{18}O is a conservative, naturally occurring tracer to distinguish between river and precipitation derived groundwater that relies on the altitude effect which results in depletion of ^{18}O in the high altitude precipitation. (Taylor, *et al* 1989:319).

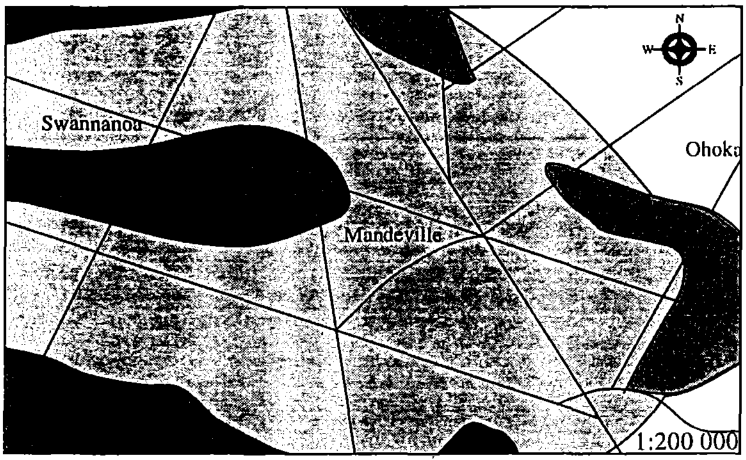
River recharge is derived from 3 main rivers in the Ashley-Waimakariri Plain that are of significance in the field area. Firstly, is the Eyre River which only flows intermittently. Its catchment is in the foothills of Oxford State Forest. The second is the Ashley River which has an estimated loss of between 1-4 m^3/s to groundwater of an annual average flow at the Gorge Bridge of 13.5 m^3/s. The Lees Valley contributes to this flow. When there is heavy rainfall in this valley, residents in the field area say that it takes three months for that water to reach Ohoka where there is a noticeable rise in the water table (pers. comm. Scott, R., Manager, Irrigation and Pumping Services, Ohoka and Wilkinson, M., local resident and contractor, 1994). This flow can be distinguished by its low pH (6.5- 6.8). Recharge also occurs from the southern banks of the Waimakariri River, feeding springs in Eastern Ohoka and Clarkville.

Rainfall is the other major contributor to the groundwater. When a soil profile exceeds moisture capacity there is a recharge to the groundwater flow. Figure 3.4 shows that the majority of the field area consists of a shallow Average Water Holding Capacity (AWHC). This is the amount of water a drained soil can hold within the root zone. It is expressed in terms of millimetres of water, and ranges from 30mm for a light soil to 200mm for a deep fertile soil. The field area is a combination of shallow to medium soils. In these areas precipitation would have a significant input to the groundwater flow. The deeper band to the West typifies less drainage because of a high water holding capacity. It is estimated by Cowie *et al* (1988), that 138 million m^3/year of infiltrating rainwater recharges the aquifers over the unconfined region. This usually occurs in the winter months.

In the summer months there is higher evaporation of moisture and if there is no irrigation and rainfall then there is no drainage.

Other potential sources of recharge are irrigation, and seepage from water races.

Figure 3.4: Water Holding Capacity in the field area.



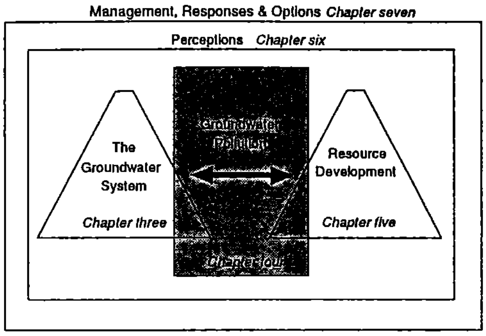
KEY
- deep 120mm average AWHC
- medium 80mm average AWHC
- shallow 60mm average AWHC
- poorly drained

After: Cowie, et al 1988

It is hard to estimate the contribution of these two recharge sources. Water races input depends on the frequency of cleaning and design. Irrigation is hard to estimate because the amount of irrigation depends on climatic conditions, types of landuse and the financial state of the individual farm owners. Comments from the pastoral farmers at present is that it is too expensive to irrigate (Norris, I., Winter, I. and McHugh, B., 1994, *pers. comm.*). It can be said however that in the field area approximately 70 percent of the land is able to be irrigated.

3.4 Summary

This chapter has illustrated the components and parts of the physical system. These have been isolated so there can be a clear understanding of the types of variables that must be looked at when researching a particular site, and the difficulties that are encountered. Setting this physical scene of the area shows how the field area is not set apart from the broader Canterbury context, but is a part of it. Understanding the geology and lithology of an area leads to an awareness of how susceptible it is to pollution. The theme of the following chapter is pollution. This chapter explains different types of pollution and the groundwater quality conditions in Canterbury and the field area.



CHAPTER FOUR

Groundwater Pollution

4.0 Pollution Characteristics

Pollution is a subjective term usually defined in terms of water as the concentration of chemical and bacteria constituents relative to a variety of potential uses. A discussion on pollution definitions was provided in the introduction. This chapter on groundwater pollution discusses attributes that distinguish sources of groundwater pollution, and the pollutants that are likely to affect the groundwater system. Groundwater quality results from the Canterbury region are used to illustrate the general quality of Canterbury water. This highlights regionally significant pollutants. The field area's water quality data can be compared to this data.

Groundwater quality is a consequence of natural fluctuations and human activities. While human activity is the primary cause of pollution, natural fluctuations in the regional background quality can not be ignored.

Natural Determinants

As water moves through the hydrologic cycle it interacts within the atmosphere, soils and the subsurface geologic formations. This affects the chemical composition and constituent concentrations. Freeze and Cherry (1979) discussed how precipitation that is naturally acidic (pH = 5.6) causes chemical reactions with geologic materials.

Rainwater percolating through soil may increase in acidity due to plant decomposition and microbiological respiration producing Carbon Dioxide (CO_2). The leaching of soils, organic matter and rocks is influenced by pH. Hardness is an aesthetic determinand reflecting calcium and magnesium in the water. Hardness does not constitute a hazard to life or the natural environment, yet high hardness causes scale deposition and scum formation and low hardness possibly causes corrosion.

Human activity, and influence on the groundwater system is immense in terms of our ability to pollute water. As humans we are the cause of our own hazard. Domenico and Schwartz (1990) name three attributes that distinguish sources of groundwater contamination: (1) their degree of localisation, (2) their loading history, and (3) the kinds of contaminants emanating from them. There is a spectrum of source sizes ranging from an individual well to areas hundreds of square kilometres. The terms point and non-point (diffuse) are used to describe the degree of localisation of the source.

Degree of localisation

Point sources are localised or generally release contaminants from a single isolated geographical area. Point sources include for example, septic tank systems, underground storage tanks, landfills, abandoned wells, offal pits and pipelines. Because of their reasonably defined plumes, wells within these areas can be determined.

Diffuse sources occur through agricultural practices, which include; animal waste, fertiliser, irrigation residues and pesticides. Contamination of concern from these sources would include nitrogen compounds, phosphates, bacteria and chlorides. These larger scale sources produce relatively diffuse contamination originating from smaller sources whose locations are poorly defined.

Loading History

The loading history describes how the concentration of a contaminant or its rate of production varies as a function of time at the source. A contaminant can be pulse loaded, where the source produces contamination at a fixed concentration for a relatively short time. Continuous source loading occurs where the concentration remains constant with time. Most long term contaminants have variable concentrations due to climatic and seasonal fluctuations. Continuing source loading can also have decaying concentrations over time such as leaching rates from a landfill site.

4.1 Water Quality - What are the Pollutants

Contaminants derived from these different sources are varied ranging from organic pollutants, biological contaminants and trace metals to nutrients. Aesthetic aspects must also be considered when assessing water quality. The different pollutants constitute different degrees of hazard potential. The different types of pollutants are discussed below. Those which are important in the field area are discussed in rather more detail.

Organic Compounds

Pollution by organic compounds can be a serious problem, as large quantities are manufactured and used. The organic pollutants which are most problematic in groundwater are mobile, toxic and persistent; including chlorinated and aromatic hydrocarbons and some pesticides (Smith, 1993a:3). Hydrocarbons are introduced to groundwater from leaking underground storage tanks, landfill leachates or chemical spills. Pesticides are introduced usually via point source errors in handling, or directly transported via a well casing or open excavation. Runoff is another source, especially from orchards.

Biological Contaminants

Biological contaminants include pathogenic bacteria, viruses, or parasites. Serious health effects can be caused through the presence of bacteria contamination in water supplies, such as, typhoid, cholera, hepatitis and giardia. Microbial contaminants are detected through a count of the coliforms present. Coliforms are bacteriological organisms. A total coliform count indicates some form of microbial presence from a number of sources including soil bacteria while the presence of faecal coliforms is more specific and indicates that pathogenic organisms may be present. Faecal coliforms have originated from the intestinal tracts of warm blooded animals. Their detection in the groundwater can be from animal waste or human waste. The New Zealand drinking water guideline for untreated potable supplies is <1 faecal coliform per 100 ml of sample. Other tests are also used to detect bacteria; as discussed later.

Groundwater becomes contaminated through disposal of sewerage via land and water, leachates from landfills and various agricultural practices. Most problems are localised, but bacteria have been found to travel up to 900 metres in the groundwater (Martin and Noonan, 1977).

Trace Metals

Trace metals such as aluminium, arsenic, manganese, mercury, selenium and zinc "...can be toxic and even lethal to humans even at relatively low concentrations because of their tendency to accumulate in the body" (Domenico and Schwartz, 1990:579). The most common sources of contamination include 1) effluents from mining; 2) industrial runoff; 3) runoff, solid wastes; 4) agricultural wastes and fertilisers; and 5) fossil fuels (Domenico and Schwartz, 1990:579). Concentrations and forms of metals can change in the water depending on the material it is travelling through. Properties are altered by pH and other material surrounding it.

Nutrients

This group of potential contaminants includes those constituents and organic compounds containing nitrogen or phosphorus. The dominant nitrogen species in groundwater is nitrate and to a lesser extent ammonium ion (NH_4^+). Nitrate is the most common environmental form of nitrogen because it is the end product of the aerobic biological process called nitrification. This oxidation of ammonia or organic nitrogen to nitrate nitrogen is a two-phase reaction commonly occurring in nature. The reaction involves the conversion of ammonia to nitrite then the conversion of nitrite to nitrate. Nitrate nitrogen (NO_3-N) is a problem in Canterbury. The NZ Standard for nitrate nitrogen is 10 g/m^3.

Important sources of nitrate are from diffuse sources such as animal farms, fertiliser applications and cultivation of virgin soils. The main concern over nitrate contamination of water is the health effects related to drinking contaminated water. In 1945 Comley initiated concern over nitrates when he reported methemoglobinemia (blue-baby syndrome) in infants was related to nitrates (Canter *et al* 1988:111). During the first year of life babies are susceptible because their stomachs are not sufficiently acidic to inhibit the microbial conversion of nitrate to nitrite. There is also the threat of cancer of the stomach, but this is so interrelated with dietary intakes, that there is no conclusive evidence to support the theory that nitrate in drinking water is related to cancer (Hardman, *et al* 1993).

Aesthetic Qualities

Drinking water must be acceptable to the consumer, undesirable effects such as tastes and odours, discolouration and blockages or corrosion of pipes have no health effects, but it is beneficial to avoid these. A number of parameters such as pH, turbidity, hardness, colour, iron and so on may require treatment. The degree of control depends on the extent of the problem. pH is a measure of the activity of hydrogen ions, H^+, present in the water. H^+ is one of the major substances that accepts the electrons given up by a metal when it corrodes, therefore, pH is an important factor to measure. The NZ Standard for pH has a desirable rate of between 7.0 - 8.5.

4.2 Problems with the Canterbury Groundwater

This section deals with the background levels of contaminants in the groundwater of Canterbury and their significance. A sampling programme to assess ambient groundwater quality has been undertaken since 1986 by the Canterbury Regional Council (CRC). The sample network consists of 144 wells located from the Ashley River to Washdyke in the South, and inland to the foothills. Indicator chemical parameters: pH, chloride, sulphate, nitrate-nitrogen and conductivity show that the quality of groundwater is generally very high and suitable for potable purposes. It is from this sampling programme that the results below have come from (Smith, 1993b).

The results show that pH varies with sample depth and is slightly acidic (range 6.1-8.1) in unconfined shallow aquifers, reflecting the influence of rainfall recharge, possible catchment characteristics and the decreasing influence of CO_2 dissolution in groundwater.

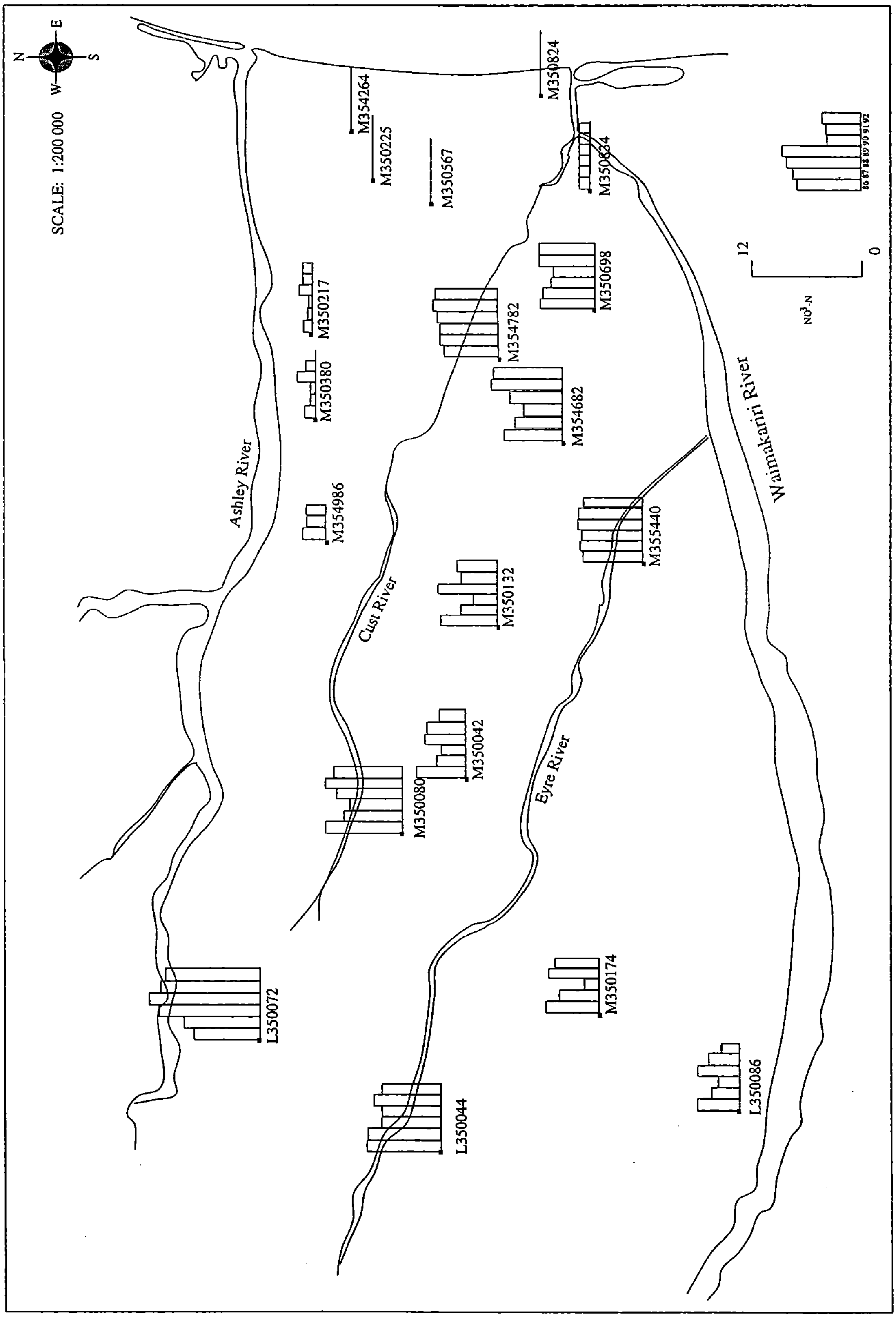
Chloride concentrations range from 1.3 - 38 ppm and sulphate concentrations range from >0.4 - 48 ppm with both anion concentrations decreasing with depth. Conductivity values are low from 6.4 - 39 mS/m, whilst nitrate-nitrogen concentrations range from 0.1 - 15 ppm.

Total and faecal coliform bacteria counts varied throughout the region, but were higher in shallow wells and when wells were located close to sewerage disposal areas (Smith, 1993b).

The groundwater quality reflects the nature of farming in Canterbury and other landuses. Some groundwater quality problems are localised such as accumulation from septic tanks while others reflect the quality of the whole system. Investigating the quality of the shallow unconfined aquifers of Canterbury indicates a problem with elevated levels of nitrate-nitrogen and coliforms. The levels of nitrate-nitrogen between the Waimakariri and Ashley rivers coincide with quality results in drainage from agricultural land, therefore, the match indicates that this groundwater consists almost entirely of subsurface drainage from the plains (Burden, 1984:112). The levels increase from the foothills to the plains and are more concentrated in shallow wells less than 30 metres.

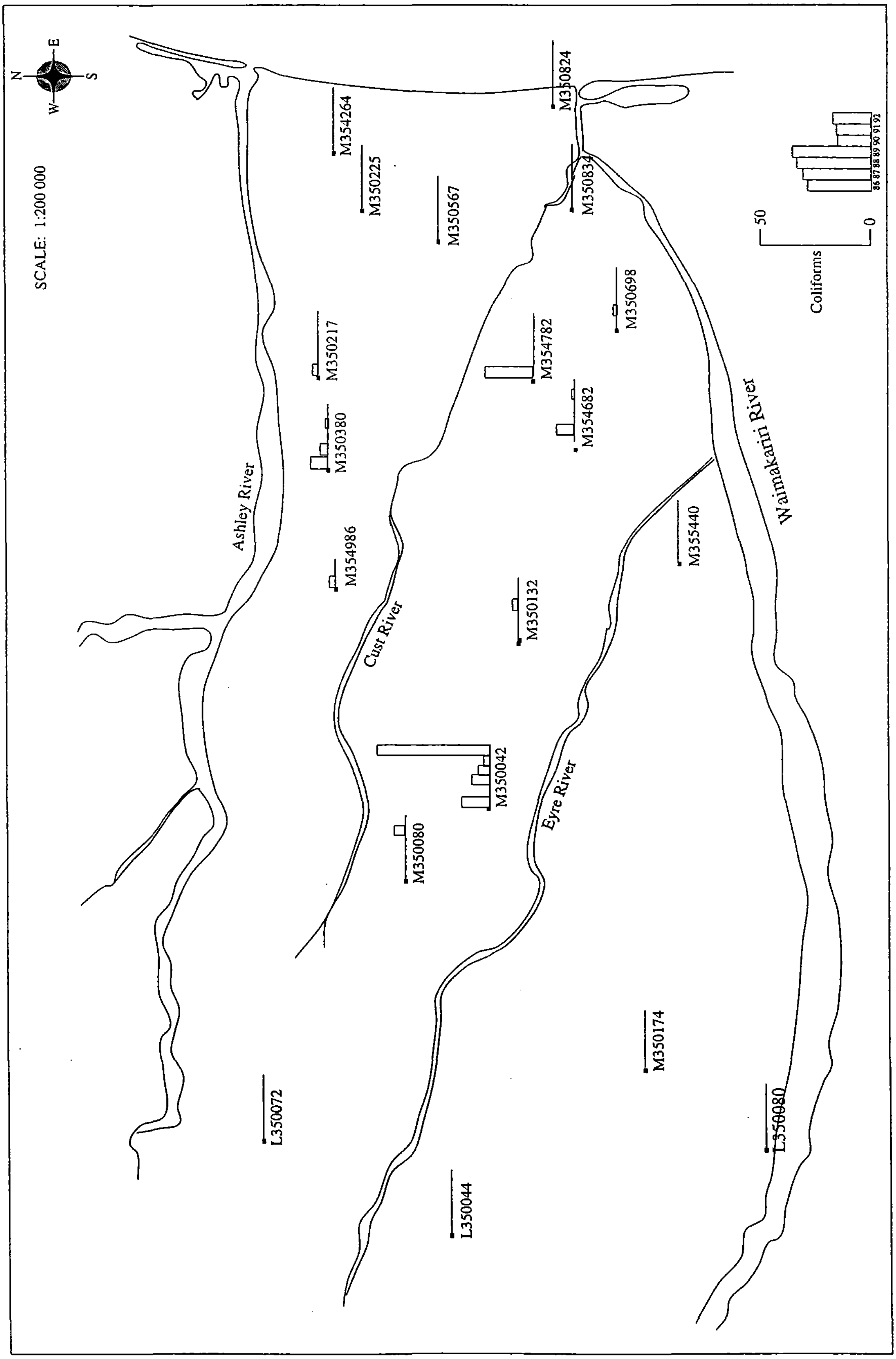
Quality analysis from bores in the Waimakariri - Ashley Plain that have been sampled more than six times are shown in the plots in Figure 4.0. This graph shows the nitrate nitrogen levels in the area. Figure 4.1 shows the total coliforms. There are spatially predominant trends in the nitrate-nitrogen plot showing that in the area that is recharged by the Ashley River and the area of confined aquifers there are low concentrations. In the central plains the area that is recharged from rainwater infiltration has higher concentrations. How does is happening in the field area compare with these broad scale water quality indicators?

Figure 4.0: Nitrate nitrogen plot in the Waimakariri - Ashley Plain



Source: Smith, 1993b

Figure 4.1: Total coliform count plot in the Waimakariri - Ashley Plain



Source: Smith, 1993b

4.3 Field Area Data

In the rural sectors of Canterbury, pollution is interpreted as the nitrates and bacteria that are present in the water and the low pH. This thesis is concerned with assessing the assumption that the groundwater is polluted with high concentrations of Nutrients (specifically nitrates) and bacteria, which are detrimental to the health of local residents. If these are found in the water then the source is considered unacceptable as an untreated drinking water source .

Data collected consists of both chemical and bacteriological information, as well as information on pH. This information was collected from a variety of sources, including the;

1) Water Quality Testing Agency,
2) Waimakariri District Council database,
3) Land owners and
4) Head office of 'Tegel' products

There was limited data available and it was rarely of the quality that was needed. Data was available however through the Council water database started in 1994. The Council database was limited because it gave the results of those wells that have failed either a chemical or bacteria test but not the complete results of the constituents measured and found to be in acceptable ranges. The original chemical results were accessed from Environmental Science and Research who did the water quality chemical testing.

Biological data were a lot harder to obtain as no accessible database was established by the company who tests for biological indicators, and few properties had been subject to biological testing. The head office of 'Tegel' in Auckland was a source of biological water quality, as it tests farms that supply it with poultry, biannually for *E.Coli* and coliforms. The field area has four farms that supply 'Tegel' with poultry.

Water Quality Results

With respect to the health of the residents the two largest concerns in the field area are bacteria and nitrates. Figure 4.2 shows a plot for nitrate nitrogen in the field area. This plot shows that there is a distribution of nitrate nitrogen g/m^3 throughout the field area. The two largest recorded levels were 9.8 g/m^3 at the Mandeville Sports Complex and 8.8 g/m^3 at the McBeth and Guy residence.

Figure 4.2: Nitrate nitrogen plot in the field area

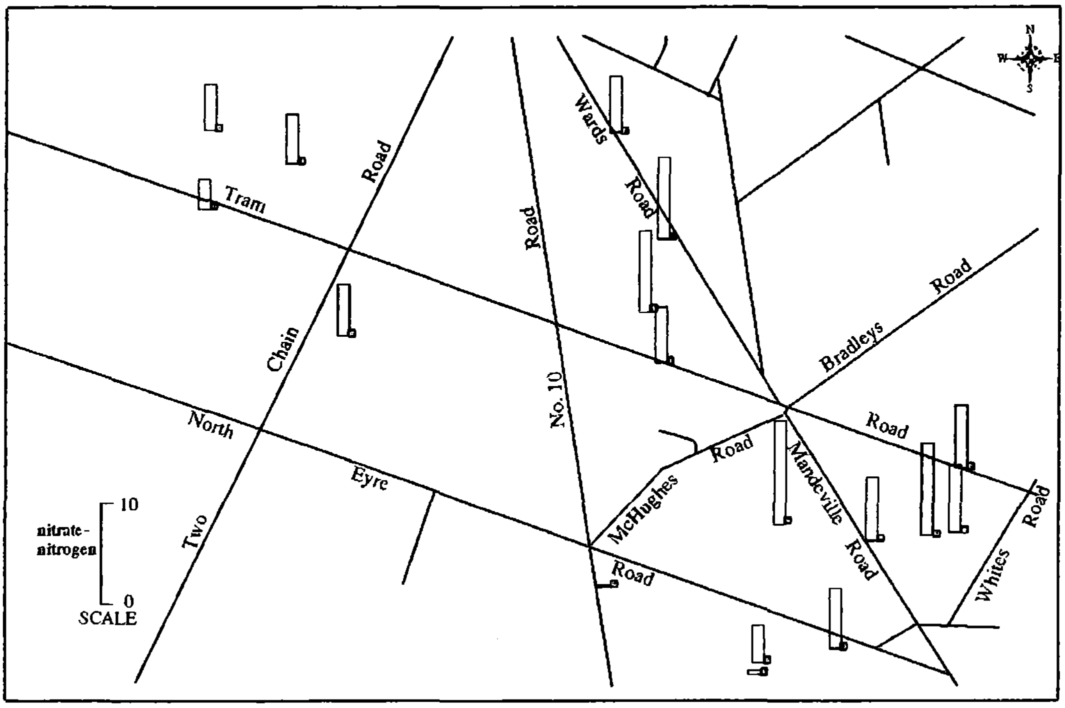
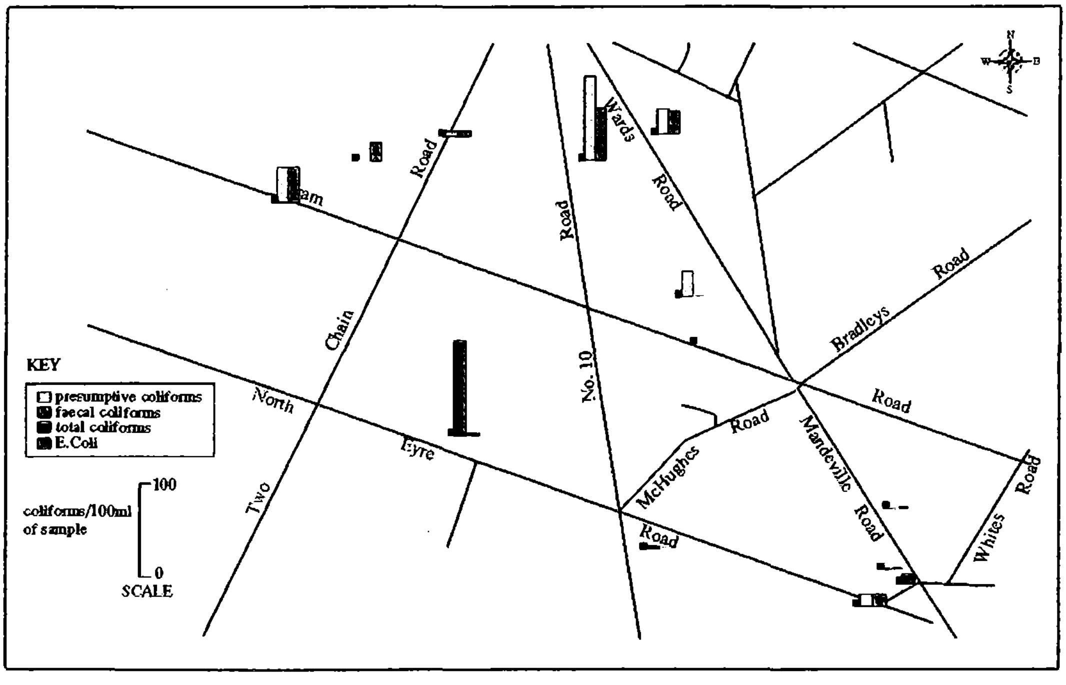


Figure 4.3: Coliform plot in the field area.



The reason for the high level at the Complex maybe explained by the spreading of manure on the property, to the development of a subdivision to the West of the well, or because the test being done immediately after a heavy rainfall. Without further work, it is difficult to determine the cause. The high levels on the McBeth and Guy property can possibly be explained by its location downstream of a mixed pig, cattle and chicken farm. The effluent from this farm is held in large pits which may leak effluent into the groundwater system.

The remaining nitrate nitrogen levels average around 5.0 g/m^3 and sources would be from non-point discharges. Wells that were tested in the field area have landuses upstream of them that are conducive to high concentrations of nitrate nitrogen such as cattle farming and subdivisions. The lower levels of nitrates (below 4.0 g/m^3) were from wells where water is recharged from the Eyre gravels and not from rainfall infiltration. The low nitrate concentrations in the North-West section of wells in the field area may relate to the landuse. As the upstream landuse is predominantly pastoral land with limited sheep farming, there is little non-point source pollution.

The coliform data are more limited and difficult to analyse. As Lester Sinton states "it is a very difficult exercise to trace bacteria sources because groundwater wanders around everywhere". (L. Sinton, Microbial Scientist, Environmental Science and Reasearch, , 1995, *pers. comm.*) The different tests used were presumptive coliforms, faecal coliforms, total coliforms and *E.coli* counts. The presumptive coliform test is the first stage of a coliform test, a cheaper test which does not necessarily indicate the presence of faecal bacteria. Faecal coliform counts are more specific and indicate that pathogenic organisms may be present. Total coliform counts indicate the presence of micro-organisms derived from a number of sources including soil bacteria. *E. coli* is a bacterium used by Tegel as a microbial indicator, because it indicates diseases in chickens and humans. It is an indicator of faecal bacteria.

The highest recorded coliform count was 100 total coliforms to 1.0 *E. coli.* This indicates that the source is not necessarily faecal, as total coliforms are derived from sources other than mammals. A possible cause for this result is that the property is downstream from large pits for burying dead chickens from a large commercial producer. But because there is a distance of 600 metres between the well and the pit, and there is limited knowledge of the groundwater direction in that particular area nothing conclusive can be said. Another well tested for water quality displays high presumptive and faecal coliform results. This property is

located downstream from a mixed sheep and cattle farm. But it is "unwise to blame this landuse unless a tracing experiment is undertaken" (*ibid*).
The pH results in the field area consistently fail, as Figure 4.4 shows.

Figure 4.4: pH levels in the field area

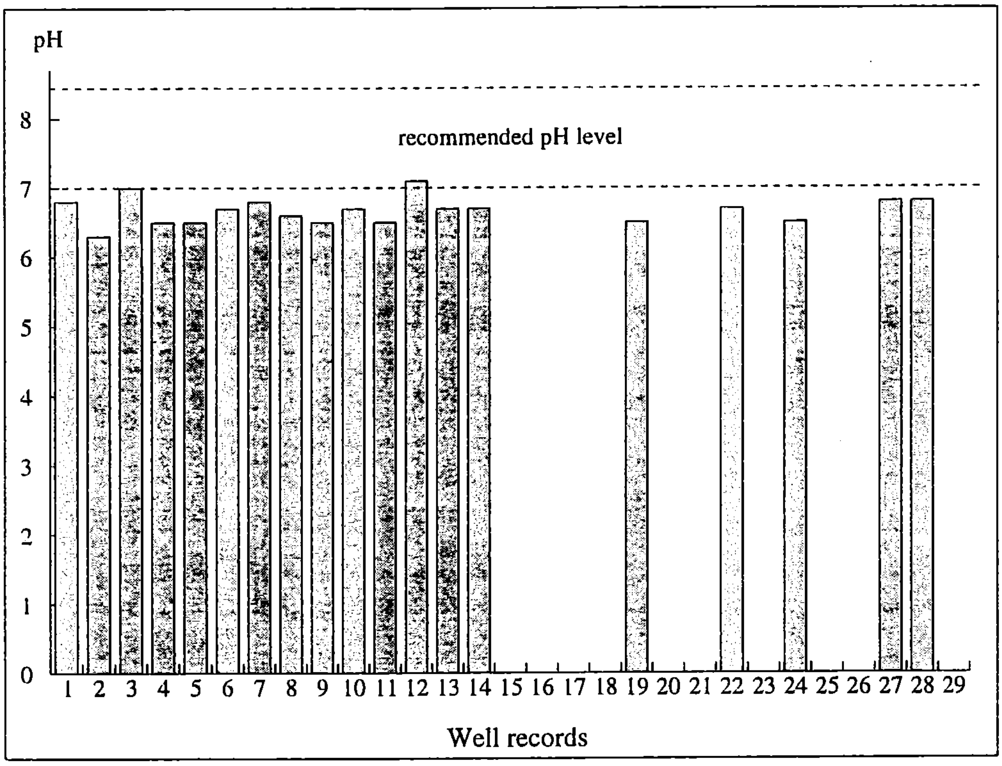
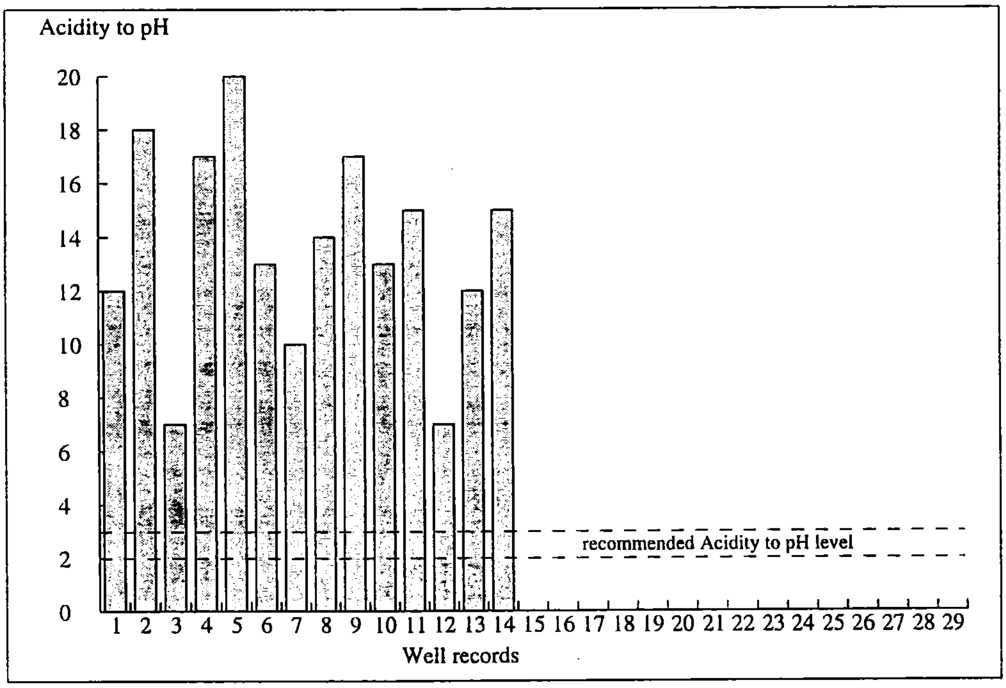


Figure 4.5: Results in field area of Acidity to pH (as CO_2)



Only two wells that were tested were within the recommended 1984 guidelines for pH. Acidity to pH (as CO^2) has a standard in New Zealand of 2-3 g/m^3. In the field area this also was consistently higher as is shown in Figure 4.5. Consequences of this will be discussed in the next chapter. No records could be found that could give an indication of the quality of water in the vicinity of the 'dump' or of the old 'dump' site, and there was not enough data to evaluate the presence of the subdivision.

What can be said however is that there is a presence of coliforms and bacteria in the area. With a tracing programme that takes into account the various landuses, the groundwater directions and velocities, and the well characteristics the sources of pollution could be more accurately assessed. But even when this was done in Yaldhurst by Sinton (1982) no correlation could be found.

The major limitation of the local data is that because they are not collected at a standard time they are hard to compare. Therefore what this data shows is general trends, and averages. These are simply records at certain times and places. Unless wells are monitored regularly then data cannot be seen as an accurate representation of the condition of the groundwater. While data can be collected and results analysed, it is harder to interpret the sources of this pollution, and therefore difficult to find solutions.

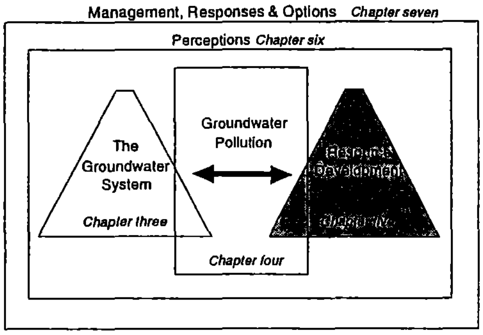
Comparing this data to the Canterbury region data, it can be seen that the nitrate nitrogen data is consistent with the local data. The areas that are river recharged have lower concentrations while the levels on the Plains that are recharged by rainwater infiltration are higher. The coliform data is inconsistent in certain wells over time, in the Canterbury region, as is the coliform data in the field area.

Groundwater pollution and its assessment remains in a state of confusion in the field area. If these variables used above are an indicator of pollution, then it can be seen that under certain spatial and temporal conditions the groundwater is polluted as measured against NZ Standards and therefore constitutes a hazard. But this does not mean that the groundwater is polluted at all times and at all places. The hazard is therefore unpredictable, it is not an isolated occurrence but fluctuating and variable.

Now that an assessment has been made on the quality of the groundwater by following the structure as developed in Figure 1.0 it stands to reason that a discussion on what the potential sources of this pollution are, and who is affected. Chapter five 'Resource Development' is a description and analysis of what is occurring on the land, in terms of the various landuses, and how this relates to pollution as well as an assessment of the water resource, and how it is utilised in terms of potability demands.

4.4 Summary

Chapter Four was aimed at identifying the nature and type of pollutants that are found in the groundwater. Canterbury groundwater quality was overviewed to understand the general conditions in the Region. This showed problems with bacteria and nitrate nitrogen concentrations which often exceeded the New Zealand Standards. The field area data showed that pH and bacteria often failed tests No records of nitrate nitrogen failed. It was found that wells that are located in zones of rainfall infiltration recharge have a lower water quality than those that are river recharged. The source of pollution in the water is difficult to find, without an extensive study being undertaken. Whether it is general conditions in the Region, or local patterns of landuse is a question for further study. Chapter five 'Resource Development' establishes patterns of landuse and resource use in the field area.



CHAPTER FIVE

Resource Development

5.0 Resource Development

The aim of this chapter is to establish patterns of resource use and development, in the field area. The two resources discussed are land and water resources. This chapter looks at patterns of change in rural sectors of New Zealand with regard to landuse, and discusses what has changed over time. Changes in landuse over time lead to changes in the way in which resources (land and water), are used and potentially abused. An analysis of the changing roles of the primary production sector provides an understanding of the increase in Rural Residential land. An increase in landuse diversity may have an impact on the water quality. At the same time an increasing amount of people are demanding water for a potable supply, thereby exposing themselves to the hazard.

The first resource discussed is the land resource and its development over time at a national level and in the field area. This resource is analysed because of its strong connection to the groundwater system through its potential for certain landuses to have a detrimental effect on the groundwater resource. While concentrating on the land resource, the main emphasis is on landuse and the associated patterns. This will focus on both rural and rural residential activities.

The water resource is discussed in the second section which focuses on the potable water needs of residents in the field area.

PART ONE

5.1 Land Resource

'Land' in this section refers to both public and private land which includes the ground as well as the soil. Land is managed by the District Council so that there will be no detrimental effects on the natural or physical surroundings. A key aim of land management is to avoid and or mitigate pollution, and to bring about the efficient use of land without being detrimental to other natural resources. Humans while living on the land, manipulate and change the environment to suit their personal needs, and the economic desires of the nation. This manipulation and use of the land has effects on the land environment, as well as impacting upon the groundwater resource. Discussing landuse and its associated patterns, shows what is occurring on the land that has the potential to have a detrimental effect on the groundwater resource.

New Zealand's History in the Primary Production Sector

New Zealand was a farming economy, depending strongly on the land based sector of the economy. When indicative planning of agriculture was introduced in the 1960s, the 25 years that followed saw an increase of 75 percent in the livestock carried on New Zealand farms (Britton *et al* 1992:96). Farming investment on pastoral farms increased with the development of farms and improvements resulting in increased use of fertiliser. To uphold production, rye and clover grasslands needed temporal addition of lime to neutralise the soil and superphosphate to stimulate growth, and natural nitrogen production for plant growth. Fertiliser application increased to support the expanding livestock numbers. Table 5.0 shows the fertiliser spread over the country from 1965 to 1992.

Table 5.0: Fertiliser spread (tonnes)

Date	Fertiliser
1965	1 888 500
1970	2 003 800
1980	3 596 593
1987	1 723 485
1992	2 407 303

Source: Statistics New Zealand, 1994

Clearly there was an increase up until the early 1980s then a decrease of 108 percent from 1980 to 1987 and a build up again in 1992 to nearly 2.5 million tonnes.

Whether the increased stock numbers and fertiliser in Canterbury would have had a marked effect on the levels of nitrates and bacteria in Canterbury groundwater is unsure. No reliable evidence from tests is available but, with the knowledge available today on potential causes of nitrates and bacteria in groundwater systems an increase in levels is likely.

In 1984 review papers given by Treasury to the incoming Labour government stated that the land-based industries were full of inefficiencies and hence they proposed policy solutions (Britton *et al* 1992:91). Deregulation in 1984 overturned preconceptions relating to farming. Deregulation led to the removal of support and assistance to agriculture including farm subsidies, resulting in a 'rural crisis' in the farming community. The 'rural crisis' had effects on interest rates, land values and exchange rates. This resulted in a growing farm debt and decreasing returns for farmers. Impacts on farm livestock levels were shown through a contraction in the use of fertiliser, livestock units and farm expenditure.

Diversification was the only option open to farmers. Looking at farm types for the decade from 1982 to 1992 over the nation, patterns can be established which illustrate this theory. Rural land-based production moved in several directions at once. Sheep, beef and mixed livestock farms declined by 7 percent. The largest increase was in horticulture with an increase of 52 percent. Cropping, poultry, pigs and lifestyle blocks increased by 26 percent. In terms of total area of farm land the beef farm increased by 111 percent, horticulture increased by 96 percent. However farms occupied by sheep production decreased by one third. Table 5.1 shows this below.

Table 5.1: Farm Type by Hectare - 1982 and 1992

Farm Type	Percent Change
Dairy	21.10
Sheep	-32.70
Beef	111.00
Horticulture	96.49
Other	-93.15

Source: Statistics New Zealand 1994:21

Changes in patterns of agricultural landuse are also seen with a decline of 5 percent of total area in grassland from 14.2 million hectares in 1982 to 13.5 million hectares in 1992. Over the same period exotic forests increased by 39 percent. The number of farms with forest areas of no more than 20 hectares has increased by 31 percent. This shows how forestry is being used in conjunction with other forms of farming.

Another indicator of diversification is a change in farm size. The average size of horticultural farms increased by 28 percent. In contrast the average size of sheep, beef and mixed farms decreased by 4 percent over the decade. The number of farms that are under 19 hectares, which would include lifestyle blocks, has increased by 32 percent between 1982 and 1992. The main category consists of those who engage in beef farming. These having increased by 95 percent. Deer farms under 10 hectares have grown by 254 percent. (Statistics New Zealand, 1994:21). These are the national statistics which indicate definite patterns of change in the rural sector.

With a downturn in the rural economy, which began in the 1980s, farmers were no longer able to support the lifestyle to which they had become accustomed. Subdivision was an option that allowed an income for retirement, or to act as a supplementary income. It was an option on the land that brought large returns for only an initial outlay. A strong counter to subdivision is the argument of protecting high quality soils in the subdivisions. This is not a problem in the majority of farms in the field area as the soils are stony and of low quality. With a lot of the land idle with scattered sheep, subdivision seems to be a viable option. Property is therefore available for predominantly Christchurch residents, and also other residents from within the District and further afield. With this subdivision and development comes the requirement of providing a safe environment for the residents.

The Waimakariri District

At the district level it can be seen that there has been an upsurge in the amount of rural residents in the Waimakariri District (WD) in the last 5-10 years. The total building permits issued for dwellings increased from 141 in 1986 to 363 in 1992. In the rural sectors of the District in 1986 there were 53 new dwellings issued building permits compared to 121 in 1992 (WDC, 1993). The WD is the second fastest growing district in the South Island. The growth is centred around the main towns of Kaiapoi, Rangiora, Oxford and Woodend but is also substantially important around smaller towns and residential areas such as Ohoka and Mandeville. The growth in the rural areas comes in the form of rural subdivision and rural residential subdivision. Thirty six percent of holding sizes of rural properties are less than 2.9 hectares (WDC, 1993). There are both push and pull factors are involved with the growth.

The push factors involve Christchurch City Council policy to contain the city within a greenbelt, which restricts locations in which to live. It therefore pushes the residents beyond the city limits to growth points such as Kaiapoi and Rangiora in the north. Travelling only 15 and 25 minutes respectively to Christchurch is not seen as a barrier. Mandeville which is located only 20 minutes drive to Christchurch, is therefore looked upon favourably as a place to reside. Pull factors are associated with some perceived aspect of the rural environment; space, peace and quiet, rural scenery and fresh air and the idea that the rural lifestyle offers "healthier living" (WDC, 1991:7).

5.2 Uses of the land resource at Mandeville

The land resource at Mandeville and its use consists primarily of agricultural farms and rural residential living. Grazing animals, predominantly cattle and sheep, make up the majority of the land used while smaller farms have more diversified landuses. Different landuses have different impacts on the land and hence on the groundwater resource.

Farm Size

Farm sizes have changed dramatically in Mandeville in line with the national changes that have occurred. The largest properties in the field area are owned by longstanding established families with sheep farms. One of the largest properties is a 140 hectare mixed sheep and beef farm. In Area A in Figure 5.0 thirteen properties are between 10 and 12 hectares. The 10 hectare block is one of the most popular subdivision sizes for a "hobby farm". Another popular size is between 3 and 6 hectares which can be seen around Area B. The smallest size sections are those located in the rural residential subdivision which is located in Area C.

The farm sizes reflect the field area's location to Christchurch. People living on these smaller properties of less than 12 hectares tend to derive their primary income from work in either Christchurch or a settlement nearby such as Kaiapoi

Figure 5.0: Property sizes in the field area.

Source: Author, 1994

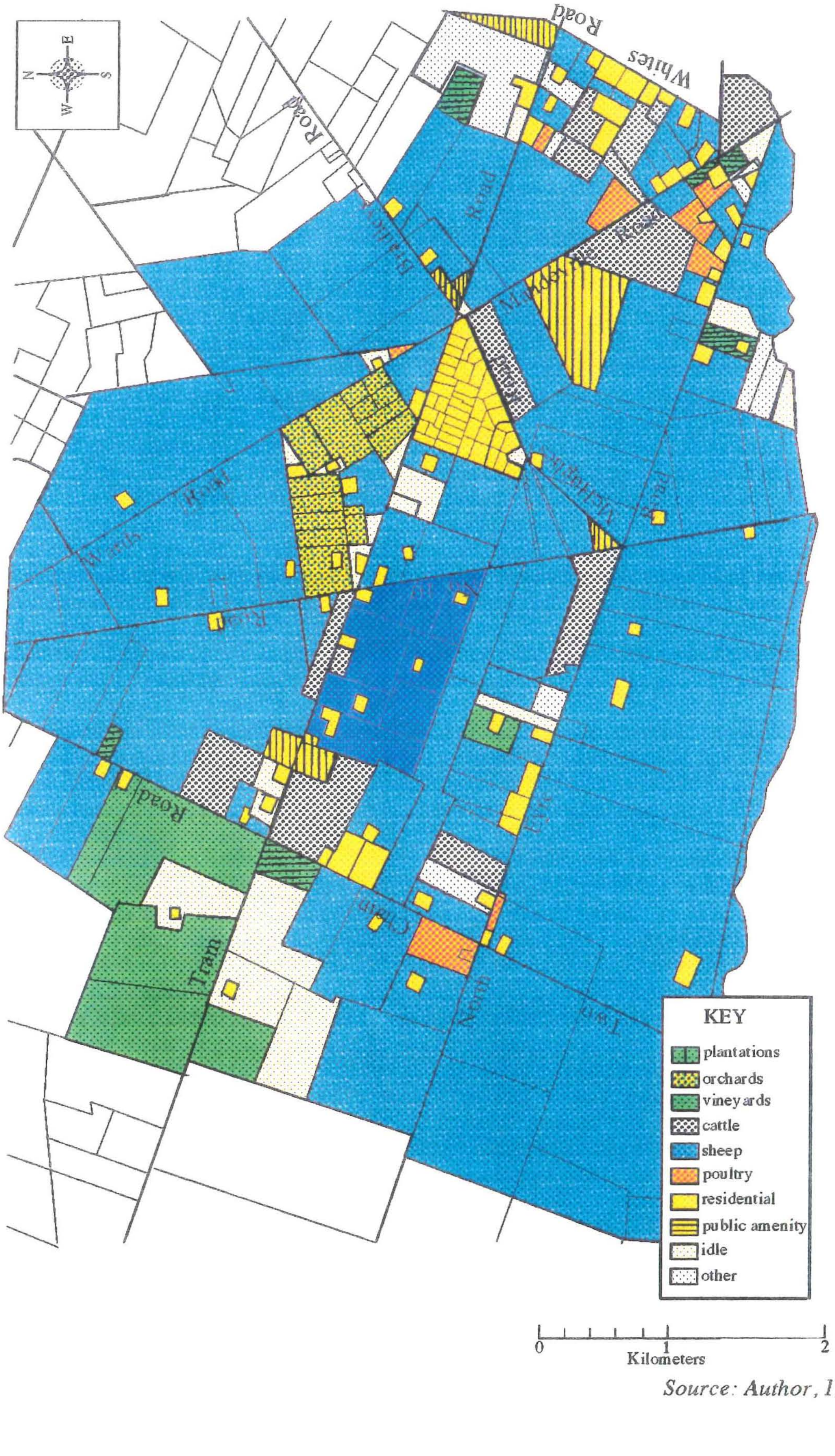
or Rangiora, or they are retired. Any farm income is secondary, the farm is usually a hobby. Rural residential blocks are on land which has limited agricultural or pastoral use or returns because of high rates and costs of the land. Therefore a favourable option to the landowners is housing development, for example the McHugh and Fitzgerald blocks in the field area.

Land Use in Mandeville and its impact on the groundwater resource

Figure 5.1 shows the predominant land use in the field area as sheep farming. This is especially the case on the larger properties with established long term ownership. On the smaller properties sheep are run mainly to keep the grass down. There are 180 hectares used for cattle farms in the field area. The eight cattle farms consist of approximately 150 grazing dairy and 350 beef cattle.

Nitrate contamination in New Zealand is associated with intensively grazed grass/clover pastureland. The organic waste excreted by grazing stock in this country is equivalent to a population of approximately 250 - 300 million (Burden 1982). This contributes about 92 percent of the total nitrate nitrogen (NO_3-N)

Figure 5.1: Landuse in the field area



Source: Author, 1994

load (Burden, 1984). Freely grazing animals are inefficient distributors of nutrients, depositing high rates on relatively small areas. The presence of urine and dung in concentrated spots at the soil surface favours nutrient loss by leaching (grazing stock deposit urea-nitrogen at a rate of about 40 - 70 kg/ha/y for typical stock levels). Cows excrete large amounts of urine which cannot be utilised and it therefore infiltrates into the groundwater system. Cows favour water courses and this behaviour is responsible for the introduction of large quantities of nutrients in water courses. Sheep in particular form camps at which considerable quantities of nutrients are deposited.

It is the opinion of the Water Quality Officer at the Canterbury Regional Council that non-point sources such as grazing animal effluent are the main cause of high nitrate levels in the Canterbury area. (V. Smith, Water Quality Officer, CRC 1994, *pers. comm.*). After irrigation or rainfall these excess nitrates infiltrate through the free draining soils and enter into the groundwater system.

Horticulture evolved as an export opportunity in the 1980s and since then orchards have become scattered around the Plains. Horticulture is the next largest land use in the field area. The most established orchard contains nectarines and apples, and was once approximately 50 hectares in size. Established in the late 1980s this orchard has since been subdivided into smaller sections and is also suitable for vineyards. In the last two years, more orchards and vineyards have been established on the free draining soils. These can be seen in Figure 5.1. Land is being bought in blocks, planted in vines, then sold off in subdivided sections.

Other horticultural activities in the field area include walnut farms, an elm tree farm, a strawberry and potato farm. The whole area in horticulture would be approximately 220 hectares. The result of more intensive use of the land via horticulture is that there is an increase in the use of sprays including fertilisers, pesticides, insecticides and herbicides. The potential influence of this is that sprays can enter streams, water races via runoff, and infiltrate into the groundwater system as well as being windblown into surface water. With increased tillage and ploughing, nutrients are also lost and leached into the groundwater system.

Other landuses in the field area which have the potential to be detrimental are poultry and pig farms, with their associated activities. The field area has six poultry farms, these include turkey and chickens for both meat and egg production. It was on a poultry farms twelve years ago, that a poultry owner was alerted to the pollution in the well water. Chickens were dying and when the water was tested it was found to contain very high counts of faecal coliforms. This was occurring at a time with very high rainfall and a high water table. (R. Wix, Poultry Farmer, 1994, *pers. comm.*). Whether these high readings were from a specific pollution source or these were the general water conditions in the area are unknown as there are no records.

All poultry farms witnessed had large offal pits for the disposal of carcasses. One observed by the author was 2 metres in diameter and approximately 3 metres deep. These pits last between 3 and 4 years. Another observed was at the back of a property and was in a reworked area of about 20 by 30 metres. The disposal of dead poultry is now contracted out to agencies. One particular company which has three farms in the area informed the author that the frozen carcasses must be removed from the property for disposal. However, complaints were voiced from residents neighbouring the poultry farms, that 'huge' pits were dug to dispose of dead carcasses. The neighbours feel that these pits are the cause of their 'bad' water quality. Therefore to the residents living adjacent to the poultry farm this activity is perceived as being the main cause of groundwater pollution. Every rural property contains an offal pit of some form, and these are especially important to ground water pollution if they are deep enough to reach the groundwater level.

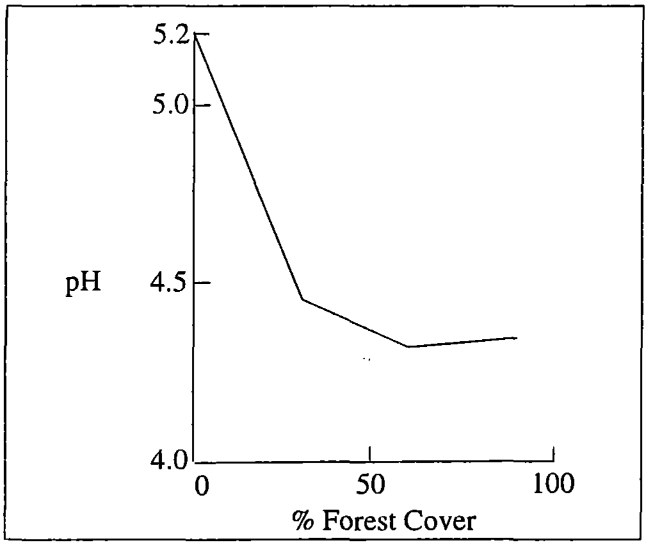
The other main byproduct from poultry is the waste produced by the birds. In most farms disposal of effluent is also contracted out. Waste can be used as a mix for compost or it is sprayed or spread on land. Another popular waste product used for spraying is pig effluent. This is spread minimally in the field area according to the land owners (approximately 40 hectares annually are sprayed). Yet while in the field area, a truck was observed spraying a paddock not mentioned by the farmer. Farmers deny applying effluent if they have not gained consent to do so. Any animal effluent collected and spread at a rate greater than 2 000 litres per day, must have a discharge permit. Land spread animal waste will have a smaller impact on groundwater quality if controlled smaller applications can be made at increased frequencies. Where possible these should be timed to coincide with uptake demands of the crop or pasture over the growing season, and avoid spreading during heavy rains (Dillon *et al* 1989:354).

A study undertaken by Singleton from Landcare Research noted that "farmers have traditionally used freely draining soils for disposing effluent" (in Cotterall-Fisher 1994:7). It is known that spraying sludge and effluent onto freely draining soils can have a detrimental effect on the groundwater. Nitrogen in effluent breaks down to ammonium and nitrate. Under normal conditions in free draining soils the nitrate travels straight through the soil where it may contaminate the groundwater. (Cotterall-Fisher, 1994:7). Therefore this activity may be contributing to the high nitrate levels in the region.

A landuse that has also increased in the field area similar to the national trend, is the increase in exotic plantations. Approximately 30 hectares are planted in *pinus radiata* and gum trees under 5 years old. These are located in blocks that surround a residency and in a block in isolation. Blocks of this size have little if any known effect on the water system. Yet larger plantations of exotic and indigenous trees are found throughout the catchment and especially in the upper catchment. The Ashley Catchment which recharges the groundwater in the field area is a forested catchment. Trees take up nutrients for growth, including ions which could potentially be used to neutralise acids (Mason, 1991:145). During autumn leaf fall and the activities of scavengers lowers the pH of the water running through the forested areas. These activities are a possible explanation for the low pH that is characteristic of water from the Ashley Catchment which is between 6.2 - 6.9, compared to 7.0 - 7.6 at the gorge of the Waimakariri River. As a comparison Figure 5.2 is a correlation between forest cover and the pH of water from streams in adjacent catchments in Scotland.

Ploughing and disturbing the soil stimulates microbial ammonification of organic nitrogen released from decomposing roots and present in soil. Subsequently nitrification produces nitrates which in the absence of growing plants is readily leached. When land is ploughed, therefore, there is an increase in nitrates in the groundwater. Ploughing is common with resource-seeding pastures as well as establishing new crops or preparing land.

Figure 5.2: The effect of afforestation on mean pH in streams in adjacent catchments.



Source: Mason, 1991:145

An activity that can also have a marked effect on the water quality is irrigation. Irrigation practices include border dyking, spray irrigators and sprinkler or trickle systems. Sprinklers and trickle systems are popular in orchards and other horticultural activities, and in gardens. Border dyking is not used in the field area. The common form of irrigation is the sprayers. These come in a length of small sprayers or a single large sprayer. The use of irrigation is largely dependent on three factors. First the weather conditions, secondly the type of landuse and thirdly the price.

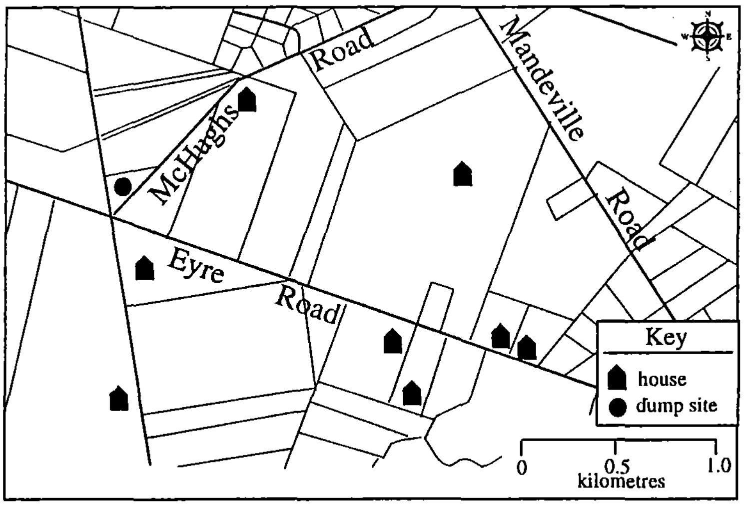
Irrigation can reduce water quality by decreasing water flows and increasing the concentration of mineral salts. Irrigation results in an increase of drainage through the soil. Where irrigation recharges the groundwater, irrigation is found to increase leaching of plant nutrients, particularly NO_3, from irrigated areas (Adriano *et al* 1972). This leaching will occur throughout the 12 months beneath irrigated land, while other works found no increase in NO_3 (Carter *et al* 1971). In Mid-Canterbury Quinn (1977) found that during the irrigation season (October-April) 70-130 kg/ha of NO_3-N was leached from irrigated pastures with at least 60 percent of that coming from urine patches. Additional losses during May-September were less than 20 kg/ha. This is approximately 80-140 kg/ha lost annually. Annual leaching losses from non-irrigated land were estimated to be less than 30 kg/ha. Leaching can be reduced by improved control of irrigation application and by increasing the frequencies of irrigation using smaller water volumes in each application. Potential NO_3-N losses should be considered in relation to irrigation schemes and the development of new schemes.

An irrigation scheme proposed for the area can be seen in Appendix 6. It shows the extent of the area to be serviced. Originally designed for irrigation it will extend to stockwater race systems, adding to the Ashley and Cust Rivers when they are low and recharging the Eyre gravels to maintain groundwater levels, and possibly power generation. Potential impacts of the scheme development will be to raise summertime groundwater levels beneath and downstream of the scheme.

Artificially recharging the aquifers, if not managed properly, can lead to drainage problems especially in the confined aquifer areas where drainage is already a problem in times of high rainfall. The surface irrigation will further deteriorate the nitrate and coliform levels in the unconfined aquifer. The scheme suggests a piped drinking water supply throughout the area (Pattle Delamore Partners Ltd 1993). The use of land for irrigation plays a major part in the potential impacts upon the groundwater system, extending way beyond the boundaries that are shown in Appendix 6. Before any major developments are undertaken these factors should be looked at carefully.

A landuse that is scattered around the Plains and is present in the field area is refuse sites. "Dumps" as they are commonly called, when developed in the past were just as the name suggests. Rubbish of all types was dumped into large pits, which were often abandoned shingle pits, and either buried or burnt. Leachates from dumps can be very toxic and have detrimental effects on the groundwater system many years after use as material continues to breakdown. Both organic and inorganic compounds are found. The dump at Mandeville is not monitored so little is known about what is in it, or the effect that it is having on the groundwater system. A property adjacent to the dump site shown in Figure 5.3 is not allowed to use the water from its well because it was green and toxic (the water test results can not be found). It has water piped to it from the Mandeville Water Supply.

Figure 5.3: Location of the dump and residents surrounding it



Source: Author, 1994

Land is often idle for long periods of time because of the nature of plant growth in the dry areas of Mandeville, especially inland areas. Much of the land is dry and bare in these areas. Bare soils release more nitrate than cropped soils because of the lack of nitrogen uptake by the plant roots. In general, "under fallow one to two times more nitrate may be leached into the subsoil than under cropped land, and nine times more under grassland (Follett, 1989:78).

The diversity of landuse implies that there are a variety of potential sources of pollution to the groundwater system. The sources of pollution in a well are very hard to establish because of pollution's cumulative nature. Pollution may be as a result of a variety of one particular landuse, or a combination. Knowledge as to which source is responsible for contamination of the groundwater system or a particular well can aid management and has important implications for public health.

Along with the impacts of rural living, the implications of the increase in the urban type lifestyles can have an effect on the environment. The patchwork fields that epitomise the Canterbury landscape are being broken up into smaller sections because of the popularity of rural living, especially within 30 kilometres of Christchurch.

5.3 The Impact of Rural Residential Living on the Groundwater System

Residential living is a landuse that also has an impact on the land and the groundwater system through the disposal of effluent. It is estimated by Quinn (1974) and is still quoted in Terra Nova (Higgins, 1991), that septic tank systems serve 20% of New Zealand households with most of these using shallow soakage tiles for effluent disposal. It is this disposal of effluent and the type of systems used in relation to the receiving environment that is important in relation to the impact that the discharge will have on the groundwater system.

In rural residential subdivisions the resource conflict is heightened by the concentration of on-site septic tanks and disposal systems. The use of septic tanks to dispose of sewage is point source pollution and therefore, a local problem, yet collectively it can be regarded as a regional issue. Since the 1960s unsewered urban areas have been seen as significant 'water polluters' (Martens, 1993). Failures and generally poor effluent quality have been linked with the degradation of local surface and groundwater resources (Martens, 1993). Helen Hughes (the Parliamentary Commissioner for the Environment) says "septic tank systems are one of the most common topics of complaint in her office" (in Higgins, 1991).

Research in Canterbury

The Canterbury region has tens of unsewered settlements and nothing substantial is known about the impact of these settlements on the surrounding environment. Studies have been done by Sinton (1982) in Yaldhurst, west of Christchurch, Hughes (1993) in Oxford, North Canterbury, and the Canterbury Regional Council (1994) at Southbridge, north of the Rakaia River. A study is presently under way at the Canterbury Regional Council investigating the impact on the environment of thirteen unsewered settlements in Canterbury.

All of these studies show contamination by microbial organisms and low concentrations of chemical contaminants. Hughes in his study at Oxford found only two wells exceeded the maximum recommended nitrate-nitrogen concentrations. Concentrations of all other chemical indicators were within the recommended guidelines. Levels close to the township showed a decline in quality especially conductivity, nitrate-nitrogen, chloride, and sulphate, and a lower pH. Nitrate-nitrogen and chloride concentrations decreased as samples moved away from the township (Hughes, 1993:106). In the study at Southbridge no chemical determinands exceeded their respective New Zealand guidelines.

Microbial contaminants tell a different story. In Southbridge seven of the sampling wells show microbiological contamination. The highest level was 110 per 100 ml sampled of faecal coliforms and total coliforms were 129. Similarly in Oxford, Hughes found all monitoring wells exhibit variable levels of bacterial contamination. The majority of samples exceeded the guidelines for coliforms, more excessively in the upper zone of the aquifer and where velocities were lowest. By using an equation that incorporates die-off time, multiplied by groundwater velocities, Hughes estimated that to get the faecal coliforms concentration below 1 per 100 ml it would have to travel for a distance between 950 - 1535 metres from its source. This is in excess of Martin and Noonan's (1977) estimation of 900 metres in Burnham and Sinton's 1980 estimation of 920 metres. According to Hughes, his calculations were still an underestimation because of the presence of preferred flows. He estimated distances could extend up to 2600 metres (Hughes, 1993:108). Vertical variations were also found due to differing permeabilities. Vertical movement of microbial organisms can be retarded by horizontal layering of claybound sediments therefore a deeper well can be uncontaminated yet be located close to a septic tank disposal area.

The public health implications are paramount if the receiving groundwater is also being accessed as a drinking water supply. As the above examples show bacteria is capable of travelling large distances. But it is not only bacteria that is contained in sewage as is explained below.

Sewage Characteristics and Effects

Septic tank effluent discharge into soils carries various constituents which may degrade the groundwater. Some are natural chemicals such as chloride, nitrate and phosphate salts. Some may be chemicals such as waste oil fractions, fuel oil, and other chlorinated hydrocarbons, or anything that can be found in a house. Other constituents are parasites and microbes of various kinds. Typical characteristics of sewage effluent are taken from the sample weighted average in

Table 5.2.

Table: 5.2 Characteristics of Sewage

Suspended Solids mg/l	77
BOD_5 mg/l	142
COD mg/l	296
Tot Nitrogen mg/l	42

Source: Canter and Knox, 1985

BOD is the Biochemical Oxygen Demand, which is the contribution of organic matter. Clean water has 1mg per litre and 10 is seen as a serious pollution problem. The effluent gives rise to increasing nitrate contamination of the groundwater with the nitrification of NH_3-N in the sewage under aerobic groundwater and vadose conditions. In some cases the nitrification has been directly linked to rapid and extensive housing developments which rely on on-site sewage disposal systems (Reneau *et al* 1989). NO_3-N may be discharged directly from the septic tank or generated by denitrification processes within the adsorption system (Canter and Knox 1985).

Numerous studies have shown that concentrations of many of these contaminants in the aquifer rapidly decrease away from the immediate vicinity of the effluent discharge point. Contamination can be attenuated by processes such as: adsorption into the aquifer material or inorganic material; filtration by finer material; volatilisation; and die-off. International studies of microorganism travel, reviewed by Canter and Knox (1985), involved movement through fine-grained soils over distances of 0.8-15 metres.

Domestic wastewater contains a number of organisms which are pathogenic to humans including bacteria, viruses, protozoa and helminths. Bacteria can be transmitted through consumption of contaminated water where effluent is discharged.

The majority of enteric pathogens die-off outside the human gut, but indicator bacteria such as *E.coli* will persist for longer periods. Salmonella species may survive 11-280 days in the soil. Viruses can enter groundwater through contamination by poorly treated effluent. Coarser grained soils, which allow rapid percolation of sewage, are those which allow the passage of virus-laden water because viruses tend to adhere to finer particles (Wellings, 1982).

Protozoa and helminths may also be present in effluent particularly where the sewage tank has been neglected, abused or inadequately desludged. When soils receive septic tank effluent they act like a sieve trapping large parasites like flatworms. Protozoa can survive for days in soil. Giardia is known to survive for more than 2 months at 8°C, 1 month at 22°C and four days at 37°C (Morrison, 1992). Table 5.3 shows the incidence of Salmonella, Campylobacter and Giardia in Canterbury.

Table 5.3: Incidence of Salmonella, Campylobacter and Giardia (rate per 100,000 pop)

	NZ	WDC	SDC	CCC
1991 Year				
Campylobacter	126.1	216.5	175.4	197.1
Salmonella	37.8	66.9	63.3	39.8
Giardia	80.8	78.7	63.3	15.7
1992 Jan-Mar				
Campylobacter	39	129.9	102.3	80.6
Salmonella	14.5	19.6	0	14.6
Giardia	24.9	47.2	14.6	17.1

WDC Waimakariri District
SDC Selwyn District
CCC Christchurch City

Source: Morrison, 1992

The Waimakariri District has a consistently higher incidence of enteric infections than other areas in Canterbury, and the national average. Rural local authorities have higher rates than the city. A major difference between city and rural water is the supply locations. In Canterbury water comes from shallow aquifers in the rural areas, the disposal of effluent is in the same aquifers. Rural living can therefore be associated with a higher health risk.

What are the Treatment and Disposal Alternatives?

There are three options: 1) on-site collection and disposal,
2) on-site collection and reticulated disposal or
3) reticulated collection and disposal

With the emphasis being on the end result the CRC are not focussing on the design of systems but the treatment standard. A design must allow for a quality of effluent after treatment that is less than 1000 faecal coliforms per 100ml sample. Boulder pits and discharge bores are no longer permitted in areas with shallow groundwater (less than 30 metres to the surface) therefore these are no longer an option. In the field area 67 percent of tanks are using this method for disposal.

On-site septic tank systems

It is out of growing public and scientific awareness of degrading water bodies that the operation and performance of conventional septic tanks and disposal systems are being questioned and new domestic wastewater treatment technology has become available.

The function of the conventional septic tank is to receive sewage and hold it. During this detention period floatables, including fats, grease and oil, float to the top and undergo some microbial decomposition. Sewage sinkables settle on the bottom where they undergo decomposition due to the anaerobic environment, where it becomes sludge. In between these is the translucent layer which trickles through a flow pipe where it is discharged to the soakhole or trench line system. Vents are needed to release gas and to prevent back-draining to the house (Kaplan, 1991:14).

This conventional system has design problems. Nothing allows for the detention of the sewage. There is nothing preventing a direct flow from the inlet to the outlet pipe, or averting the re-suspension of solids. The conventional tank produces, therefore, a poor and variable quality effluent in terms of suspended solids (Graham 1992). These faults are overcome with the dual or multi-chambered tanks, which have settling tanks and an increased surface area where bacteria have more breeding ground.

Maintenance is often neglected by home owners, sludge needs to be pumped out every 2-5 years. A build up of sludge can overflow into the leachfield, block the disposal system, and retard the separation of solids and fat from the effluent. Many residents in the field area were often not aware of this factor and some had not pumped their tank for ten years. 'it's working fine' would be a common phrase in the field area. Public education is needed if the use of on-site septic tanks is to be successful.

There are four advantages of the septic tank according to Canter and Knox (1985);

1. Immediate cost of septic tank systems is generally far less than installing a reticulated sewage system,
2. Septic tank systems generally require minimal maintenance,
3. Low technology involved increases the possibility of long term operation without componentry failure, and
4. Energy requirements for the operation of a septic tank system are low compared to a centralised sewage treatment facility.

Disadvantages include;

1. Possible public health risk due to system failure, and
2. Potential for groundwater contamination due to chemical and microbial constituents of septic tank effluent.

Yates (1985), states several factors that may contribute to potential groundwater contamination by septic tank systems including;

1. Improper siting,
2. Improper construction/installation,
3. Close proximity to groundwater,
4. Climatic factors,
5. Hydrogeologically vulnerable sites, and
6. High density of septic tank systems.

The field area has 142 on-site septic tanks for a total of 430 people. The location of these wells and septic tanks can be seen in Appendix 7. The density of the septic tanks may be a key consideration on the overall effect of effluent discharge on groundwater quality. The rural residential zone which started development in 1989 has a concentration of 38 on-site septic tanks with a population of 136. Of the 142 septic tanks in the field area 89 of these are the conventional concrete septic tank, 124 of these are the single chamber design, and 17 have dual chambers only two in the field area have multichambers.

It is unlikely that the conventional tanks are meeting the disposal standards set by the CRC. In rural areas either a modernised tank is needed that meets the discharge standard, such as a multichambered tank, or the disposal system needs to be modified.

Disposal Systems

Soakholes are no longer acceptable as a means of disposing of sewage. Field tiles, or field drains as they are often called, are used in rural areas. Progress was needed in disposal methods, the traditional soakhole or boulder pit blocks easily and directs sewage directly into the groundwater system without filtration. In a study by Sinton (1986), in a 24 hour period 80 percent of effluent from a septic tank "percolated rapidly into the groundwater...a high proportion of the effluent discharged into many soakholes in New Zealand alluvial gravel formation receives only limited treatment before reaching groundwater" (Sinton, 1986:421).

Conventional gravel filled trenches are a distribution line of field tiles or drainage coil. A common problem is that effluent leaves the distribution line through the first few gaps. In soils of moderate to high permeability effluent will infiltrate over a short distance then rapidly infiltrate into the groundwater. The gravel trenches will tend to clog over the first few gaps because of high suspended solids or sludge.

Of the total 142, there are 95 tanks which have soakholes/pits as a means of disposing effluent. 47 have trenches as a disposal system which includes the modern sand filled trenches and the older field tiles.

The Dunedin City Council has decided that

> "Septic Tank Soil Absorption Systems (SASs) based on conventional trenches constituted a dubious and uncertain technology that should be avoided where possible and warrants a cautious and conservative regulatory approach. They decided not to allow any new installations of 'conventional' on-site systems or conventional use of the old technology"
>
> (Graham, 1992:4).

Other Councils have taken a similar approach in Canterbury including Selwyn District Council who have various standards for different locations depending on the lithology, location of wells and so on. In this district effluent must be contained within the boundary of the property. This approach is needed so as to avoid the health risk to the public and the environmental damage. It is easier to treat the source of pollution through more effective septic tank systems than to have restrictions downstream and have to clean up the groundwater.

There is a demand for "innovative/alternative technology" (Graham, 1992), systems that do not solely rely upon treatment by the native soils. Such disposal systems are;

1. a trench filter with percolation through a 'suitable media',
2. a package plant which digests, aerates, clarifies and disinfects effluent,
3. a mound system using sand or sphagnum peat,
4. evapotranspiration systems, irrigation systems, wetlands,
5. UV disinfection, or
6. systems based on the separation of toilet waste and greywater.

In a built up area such as rural residential subdivisions such treatment may be adequate, but there are doubts whether this treatment will be efficient enough. The doubts are not often with the systems but of the capabilities of the individuals who operate them. Therefore an alternative is a reticulated system in residential areas.

A Reticulated Sewage System

This is a more expensive form of disposal of effluent yet it is an option that is being chosen for developments. An example of a development central to the field area involving a reticulated system is given below. Health Link South and the Canterbury Regional Council find reticulating a sewage system as being very important to a new development. Dianne Morrison of Health Link South stated "individual septic tanks are not sustainable management especially in rural residential subdivisions in the Waimakariri District Council" (D. Morrison, Health Officer, Health Link South 1994, *pers. comm.*). In late 1990 a proposal to the Waimakariri District Council took place involving a Scheme Change to the

Eyre Scheme (Change 15), to convert 86.8 hectares of Rural 2 (Mixed Farming) land to Rural Residential land. The area involved was shown in Appendix 1. The Change became operative in February 1994. The decision was made after a Planning Tribunal order.

The issue of debate for three years was over sewerage reticulation and whether it should be included in Change 15 as a requirement. The opposition by the former Canterbury Area Health Board was because of the lack of a reticulated potable water supply before development. The absence of a reticulated sewage system "could compromise public health in the area" (Morrison, 1991). The Canterbury Regional Council did not want development "until a reticulated sewage disposal system is available or committed for development" (Fietje, 1991a).

A community reticulated system proposed for Mandeville is in use in Oxford. Approved by the Canterbury Regional Council, it uses on-site septic tanks which discharges effluent into an individual pumping chamber which pumps into a pipeline reticulated system to a centralised intermittent sand filter treatment plant. The Waimakariri District Council was sceptical of this system because of previous failures in Ohoka of sand filters, and because it was technology that had not proven itself in New Zealand. Yet this system provides one point source discharge as opposed to the multiple point discharges with on-site sewage tanks. While this system appears to be operating efficiently, the Waimakariri District Council have agreed to take over operation and maintenance of the system at Mandeville.

The Waimakariri District Council have realised that they need policy on Rural Residential sewerage disposal, and in 1993 Garth James (Services Manager, Waimakariri District Council) suggested that a policy decision be made to "require all rural residential development to install a community effluent and disposal system" (James, 1993:7). After installation the Council will accept responsibility on behalf of the residents.

What is the best practicable option?

Under s108(1)(e) of the RMA the holder must "adopt the best practicable option to prevent or minimise any actual or likely adverse effect on the environment..." Subject to this subsection there must also be a regard to the nature of the discharge and the receiving environment and other alternatives and that the most efficient and effective means of preventing of minimising any actual of likely adverse effects on the environment (RMA s108(8)). For on-site treatment/ disposal of sewage to successfully provide the same level or higher of health and environmental protection then management plans must be established that ensures a high standard of selection, design, installation, operation and monitoring of on-site systems. Unless monitoring of the groundwater quality is undertaken the various systems used can not be assessed.

If the on-site systems prove to be reliable then the costly reticulated system may not be necessary. Either residents must be made responsible, with permits for system operation, and education, or the company that installs the system must be responsible for its maintenance and operation. Another option is centralised management by district councils with a database approach to administration, extensive training and a monitoring system. This information needs to be systematic and complete for an accurate analysis of a system and its effects on the groundwater system.

5.4 Summary of Part One

The various landuses in the field area are examples of what is occurring at the local scale. The effects of local activities have an impact on the immediate environment. The presence of faecal coliforms have site specific influences on the groundwater quality yet other activities on the land such as grazing animals and autumn ploughing can have a cumulative affect on the quality of the groundwater, deteriorating the quality of the water by adding to the problem of of high NO_3-N.

Water quality issues are not only confined to single properties, where avoiding polluting your neighbour is important; it is also a catchment wide issue, where farm management techniques must be adopted to protect the water quality of the region. Further intensification of landuse will increase NO_3-N concentrations according to Burden (1982). Further studies on intensive development such as residential living, and the impact of intensive farming practices on shallow unconfined aquifers would benefit this area of study.

The important indicators to study are the presence of preferred paths, claybound material, the distance of wells from source pollutants, and the depth of wells. Knowledge of what specific landuses have the most impact on the groundwater would also be pertinent. With this knowledge it is possible to establish a drinking water supply in a location which will not be susceptible to contamination.

Water quality issues have many ramifications. In this thesis the focus is on water potability. Part two below discusses the potable water demands and how the water resource is demanded in the field area.

Part Two

5.5 Water Resources and the demands made by the population

In the above section we saw how the landuses and activities were potentially detrimental to groundwater quality. That same water is also demanded in a pure state for drinking. A continuous source of high quality water is expected and demanded as a right by many New Zealanders, whether living in the city or the country. An important resource concern is the loss or increased scarcity of the environmental quality of a resource (Rees, 1985).

No treatment is necessary for the deep confined aquifers of Christchurch water. In some areas in Canterbury however, water is deteriorating because of the contamination of the shallow unconfined aquifers. To maintain a high standard of water quality it may be necessary, in some areas to develop reticulated water supplies. The use of untreated water supplies on the inland plains may become a thing of the past, or only used in the more remote and isolated areas.

There is an increasing public knowledge and awareness about water quality issues. The presence in water supplies of *Giardia* and other bacteria makes it more important for water agencies to have a supply that is free of contaminants. The public believe in the 'clean green' image of New Zealand especially so in rural New Zealand and, therefore, will not accept a sub-standard supply.

Public Health Issue

Public health issues are generally covered under the Health Act 1956 which applies not only to human health but to the environment as a whole. The health of the residents is not only the responsibility of Health Link South in the District but also the WDC under the Health Act 1956. The public supplies must be within the standards that are set at the national level (these were reviewed in 1994). There are "trade-offs" in regards to potable water. In a water supply that is treated, the use of chemicals to reduce microbial and physical pollutants must be assessed against the risk of the chemicals themselves. This is not a clear cut decision because opinions are so variable. Chemical disinfection of water supply contamination is held in low esteem by the public, yet the public do not want their water supply to be polluted. (Bradley, 1992).

Potable water demands in the field area

As has been discussed more fully in Chapter three, the field area accesses its water supply from the unconfined gravel aquifers of the Canterbury Plains. The high yielding stratas are between 10 and 30 metres in depth. In the field area the average well depth is 18.3 metres. The shallowest well is 8.6 metres and the deepest 34 metres. The limitations of these wells is that they are susceptible to pollution from above.

The field area has approximately 120 wells. These are a combination of domestic and/or irrigation wells. Only 19 wells are solely for irrigation purposes and approximately 83 are for domestic purposes only. It is these wells that provide the potable water supplies that are important to the thesis.

Most rural properties have on-site wells, while some share with neighbouring properties. Water is needed for household use as well as watering the garden/ lawns, domestic stock and irrigation. Yet potable water is only necessary for domestic stock and household consumption. Some types of landuse, such as poultry farming are sensitive to the condition of water because of the young chickens susceptibility to bacteria in the water. On private property it is the responsibility of the land owner to have a potable water supply.

In regards to a public supply this must be potable at all times. Regular tests are necessary to monitor the quality of the water to ensure its potability. It is the responsibility of the district council to ensure this, because of the health implications to the community (under the Health Act 1956). A way to protect public bores is to establish protection zones which consist of a protected area of

1 kilometre upstream of the bore and 200 metres in every other direction. This is a rubber stamp standard (as shown in Appendix 8), that does not take into account the conditions of a local area. The water flow in the Mandeville Water Supply's Protection Zone is presumed it is not known for sure. Where it is located it incorporates into its protection zone; eight septic tanks, and sheep farms as the main landuse.

Mandeville Water Supply

Mandeville has a public well which at present services the 39 properties in the rural residential zone as well as five properties surrounding the zone. This is a restricted supply with a design volume for 39 properties at 82 m^3/day. The actual volume used from November 1993 to February 1994 was 135 m^3/day (Pinkham, 1994). To curb use over the next 3 years on-site storage tanks are to be installed and all properties put on restrictiors. In the long term the recent development proposals may mean that new wells will have to be used to accomodate the new subdivisions.

Chemical tests of the Mandeville Supply well are similar to those which are found in the North Canterbury Plains. The pH averages around 6.8. This is under the NZ Standard for pH of between 7.0 - 8.5. Nitrate-nitrogen levels in this well have varied from a high of 8.6 on 17/9/92 to a low of 4.5 on 25/7/94. It is likely that this well exceeds the NZ Standard of 10 g/m^3 on occasions.

Problems encountered by the residents are, corroding pipes and joints, leading to the flooding of one residency. Dissolved substances in water have an important effect on the corrosion control. The most important indicators relating to corrosion are pH, carbon dioxide and alkalinity. Although carbon dioxide (CO^2) is considered to be an important factor in corrosion, no direct corrosion reactions include CO^2. The dissolved CO^2 concentration is interrelated with pH and alkalinity (American Water Works Association (AWWA),1990:1040). Acidity to pH (as CO^2) has a standard in New Zealand of 2-3 g/m^3. In the Mandeville Water Supply (MWS) it has varied from 2-14 g/m^3 which makes the water very corrosive. Alkalinity is a measure of the ability of water to neutralise acids and bases. The ability of water to provide a buffering against pH increases or decreases brought about by corrosion processes or water treatment chemical additions, is closely related to the alkalinity and pH of the water (American

Water Works Association, 1990:1040).

In February 1994 a meeting was held between the residents and the WDC to discuss the problem of corrosion, and a aeration plant was decided upon to reduce the corrosive nature of the water. Bacteria tests are the other source of concern in the water supply. Bacteria quality tests in the MWS have been variable. The earliest well test record that can be found by the author of the MWS water quality is shown below as Table 5.4.

Table 5.4: Results of Bacteriological tests on Water Samples from MWS

Location of test	Date	Coliforms		Total Viable Count (TVC)	
		Total	Faecal	@35°C	@22°C
resident kitchen tap	09/1/91	5	3	5.6×10^4	8.2×10^4
entering holding tank	16/1/91	<1	nil	6.5×10^3	6.7×10^3
neighbouring supply	16/1/91	<1	nil	2.4×10^4	2.5×10^4
resident kitchen tap	16/1/91	<1	nil	3.1×10^4	1.3×10^5

Source: WDC, 1991

Coliforms have been defined in the section above but in this table there is the addition of the indicator Total Viable Count (TVC). TVC is the measurement of the total bacteria count of a water sample and therefore, includes many species of bacteria. EEC standards for TVC are done at two temperatures 22 °C for organisms of environmental origin and 35-37 °C indicating organisms more likely to be associated with animal or people. The standards are shown in Table 5.5 below.

Table 5.5: EEC Standards for Total Viable Count (TVC)

TVC at 35 or 37 °C - not more than 10 colony forming units (cfu)/ml ie 1.0×10^3 cfu/100ml
TVC at 22°C - not more than 100 cfu/ml ie 1.0×10^4 cfu/100ml

Source: Department of Health, 1989

From Table 5.5 it can be seen that all TVC tests failed except at 22 °C on the water entering the holding tank. This is an old style of testing water and can be compared to the coliform test which passes all of the tests except for the first one. The reason given for this by the Environmental Health Officer (EHO) of Waimakariri District Council was that the "coliforms may have originated from the houses holding tank" (Bryant, 1991). After the original test there were no coliforms found. The author was told that it was from these tests that the reticulated system was treated through chlorination.

Water Treatment

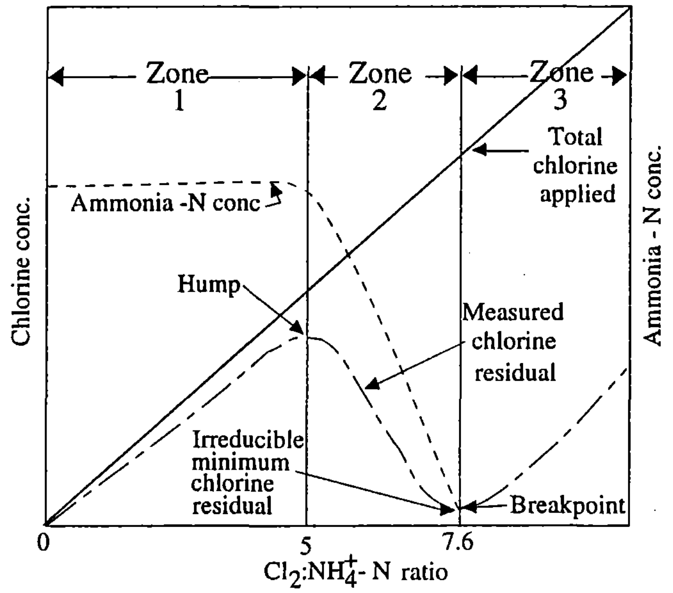
Chlorination is used to treat the Mandeville Water Supply to disinfect the water. Chlorine is the most common form of water disinfectant. From a health standpoint the omnipotence of chlorine has come into question as by-products of chlorination are identified. One organic by-product produced is trihalomethanes (THMs). A number of epidemiological studies have indicated an association between chlorinated drinking water and increased mortality from a variety of cancers (AWWA, 1991).

Chlorine can react with a variety of constituents including ammonia, amino nitrogen compounds and others. Free chlorine reacts to form chloramines (monochloramine, dichloramine and trichloramine) which contribute to the total chlorine residual in the water. If there is not enough free chlorine then the whole system will not be disinfected. Free chlorine in the system is needed to kill bacteria that lives in the pipes. If there is too much chlorine then the the surplus chlorine can leave taste and smell in the water. The amount of chlorine is dependent on the bacteria and chemical constituents in the water. The model that explains this is seen in Figure 5.4.

This model shows the "breakpoint" reaction between free chlorine and ammonia. At doses below the "hump" in the chlorine residual curve (zone 1), only combined chlorine is detectable. At doses between the "hump" and the "dip" in the curve, an oxidative destruction of combined residual chlorine accompanied by the loss of nirogen occurs (zone 2). After the ammonia nitrogen has been completely oxidised, the residual remaining consists almost exclusively of free chlorine (zone 3).

The minimum in the chlorine residual versus dose curve is called the breakpoint and denotes the amount of chlorine that must be added to the water before a stable free residual can be obtained (AWWA, 1991:888).

Figure 5.4: Schematic idealisation of the breakpoint curve.



Source: AWWA, 1991

A common complaint of the residents is a chlorine smell and taste in the water supply. This can be caused by a variety of reasons, one could be, excess total chlorine applied, another could be not enough chlorine ("hump" area in the Figure). In this case the chlorine is being used up by compounds in the water and the chloramine by-products are causing the smell and taste. Another complaint is that if the water is left to sit for a couple of days slime forms in the water. This could be due to the high hardness of the water.

The residents in the field area are not happy with the water supply, especially the aesthetics of the water, that is its taste and smell, and the fact that it is corrosive. The are also not happy with the quantities. Because it is a restricted supply the residents can not even water the garden and lawns in summer. With storage tanks on-site this should not be a problem in the future. There are plans to either move or upgrade this water supply as plans for new developments are proposed.

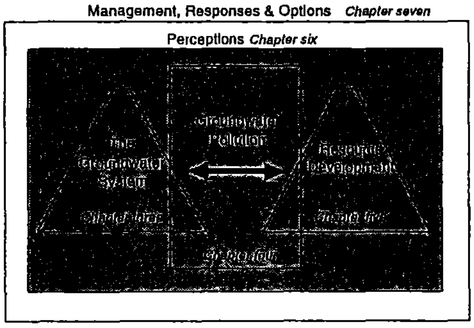
5.6 Summary of Part Two

There is only a conflict when a resource is demanded, this section has shown that there is demand for water in the field area. It has also shown the problems that are encountered when trying to ensure the health and safety of the water supply. The chemical and bacteriological problems with the Mandeville water supply were established and the treatment of that supply assessed. This section has shown the water quality demands of individuals in the field area. It is because of these personal demands and public body responsibilities that the conflict over the water resource has developed. The different perceptions of water quality is the theme of the following chapter.

5.7 Chapter Summary

Land and water resource development was discussed in this chapter. This chapter has shown how various land uses can impact upon the groundwater system. While fallow land releases high quantities of nitrate-nitrogen, the popular alternative of subdivision into rural residential blocks increases pollutants such as bacteria, suspended solids and nitrogen, which are discharged from septic tanks, which can detrimentally impact upon the groundwater system. There is therefore a trade-off between the landuses.

Conflict is apparent when this same groundwater that is being polluted is needed as a drinking water source. The resource has a dual purpose as a disposal medium and a water source, for which a quality is essential. Individuals perceptions on groundwater quality and what causes a poor water quality supply differ. Therefore there is not a conflict for all individuals. The perceptions of the individuals in the study area and other interested parties on the subject of groundwater quality at Mandeville is the topic of the following chapter.



CHAPTER SIX

Perceptions of Water Quality

6.0 The Contrariety of ideas

Studying the perceptions of the residents in the field area, and the different interested parties, on how they perceive their water quality was undertaken. This involved the use of surveys, and interviews. This method of inquiry allowed for subjective opinions not based on facts, but coming from individual points of view. Whether the groundwater is polluted or not is based on speculation. The ideas that were voiced were simply a combination of opinions, attitudes and perceptions. Secondary to, but associated with the different opinions on the quality of the groundwater, is the perception about country living. This is perceived as being a 'black and white' issue, in that land managers and members of other research institutions, feel that all residents are satisfied with their rural residential lifestyles. But as will be demonstrated these are not clear 'black and white' issues, but ideas fraught with credulity.

This chapter discusses the different perspectives that were encountered while researching water quality in the field area. The attitudes are those of the residents in the area, and also of the people who are part of the decision making process in the area, including the CRC, WDC, HLS and other research institutes such as ESR. The important focii of this chapter relates to answers to the following questions;

1) What are the opinions of the different interest groups?
2) How and why do these opinions develop?
3) Why are these opinions so different?

6.1 Recognising the importance of Perception studies

Research on perceptions, attitudes and behaviour emerged as a distinctive area of enquiry during the early 1960s. It was rooted in the environment and society research tradition (Mitchell, 1979:118). "Perception is a central, but nebulous and controversial, concept in hazard literature" (Mitchell, 1984:33). The word 'perception' is found in many published hazard studies but with little consistency of usage. In a summary of Mitchell (1984) he states "some authors refer to perception as; risk assessment made by potential victims, attitudes to environment, reported information about hazards, awareness of physical processes contributing to hazards, identification of adjustments to hazards" (Mitchell, 1984:36). Perceptions of hazards can relate to both the recognition of the processes causing the hazard, and the consequences and perceived adjustments to the hazard.

People's perceptions were seen to be an important step in the decision-making process. Perceptions are crucial to both the development of the hazard and to their solutions.

There is a changing face in environmental management, a forced and needed change that incorporates the wishes of the public to a greater degree. Under the RMA consultation, public notification and meetings are an integrated part of the decision making process. Whether it is successful or not is another issue, as is whether the public wish to participate. Many members of the community are willing to have decisions made for them, unless there is a direct impact on their lives.

When a problem or issue evolved in the past the methods used to solve it were to use technical expert evaluations and to have empirical testing. This so-called 'expert' would advise management and a rule would be made to incorporate that decision. The decision maker would act on behalf of the public without knowing what the public thought. Now it is not only important to understand the problem fully and how it relates to other variables, but to understand how this problem is perceived by the public. The experts and the public can have very different opinions and this is where conflict can arise.

The context of the thesis in relation to decision making and the perceptions of the public relates to the perceptions of water quality. As stated in the earlier chapters water quality, especially poor water quality can constitute a hazard. It is therefore important to assess how this hazard is perceived, so as to assess what responses will be made. This is presuming that there is a hazard or, more importantly, that there is a perception of a hazard. As one commentator put it, "perception may very well become more important than reality...especially when it comes to the quality of drinking water" (Thompson, 1992). Therefore perceptions provide a valid and required input to discussions on risk management. To assess the perceptions in the field area a survey was undertaken to establish how the residents in the field area perceived their water quality.

6.2 Resident Survey

The aim of the resident survey was to determine attitudes towards water pollution, to see whether there was a water quality risk, in the opinions of the residents, and what the source(s) of the pollution are. There were 102 individuals surveyed. This was an individual from 95 percent of the total occupied households in the field area. Not all of the property owners could be located for the survey, and not all owners occupied their properties. The majority of the surveys were done door-to-door. Those who were not home after three visits were surveyed by phone. The contents of the survey can be seen in Appendix 3.

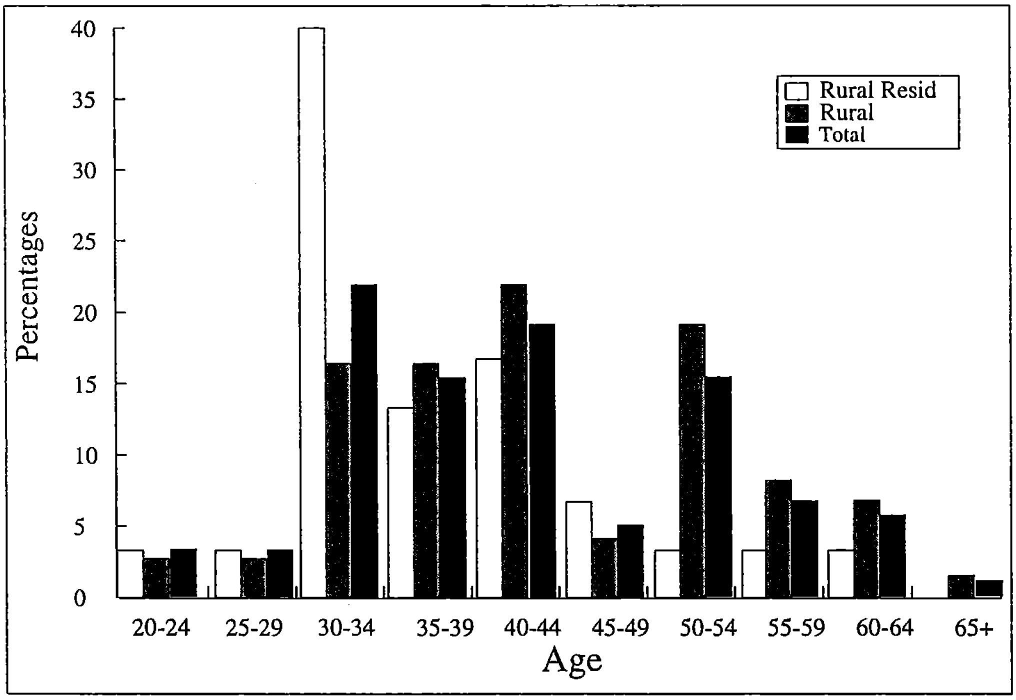
Who are the residents in the field area?

It is important to establish who the residents in the field area are. Information on such things as age, gender and occupation provide a picture of the types of residents who live in the field area. There are differences and similarities between the residents. The major differences in the types of residents are between those who live in the rural areas and those in the rural residential zone. Distinguishing between these two groups is important for two reasons. Firstly, even though they have the same source of water, the rural residential group use chlorinated water from the MWS and therefore their opinions are different from the residents who operate off their own wells. Secondly, the composition of those surveyed in the residential area is different from those who live in the rural areas. So for analysis these two groups were separated.

The gender breakdown in the field area of those surveyed were 55 (54%) female and 47 (46%) male. In the rural area 41 (56%) surveyed were females and the remaining 32 (44%) were male. In the residential area 15 (52%) of those surveyed were male and 14 (48%) female.

The Age groups of those surveyed can be seen in Figure 6.0. This shows that 70% of those surveyed in the rural residential zone were between the ages of 30 and 44. This was younger than the total of those surveyed which had 58% of the residents between this same age group. The rural population was older with 42% of the population over 50 compared to only 9% in the residential area.

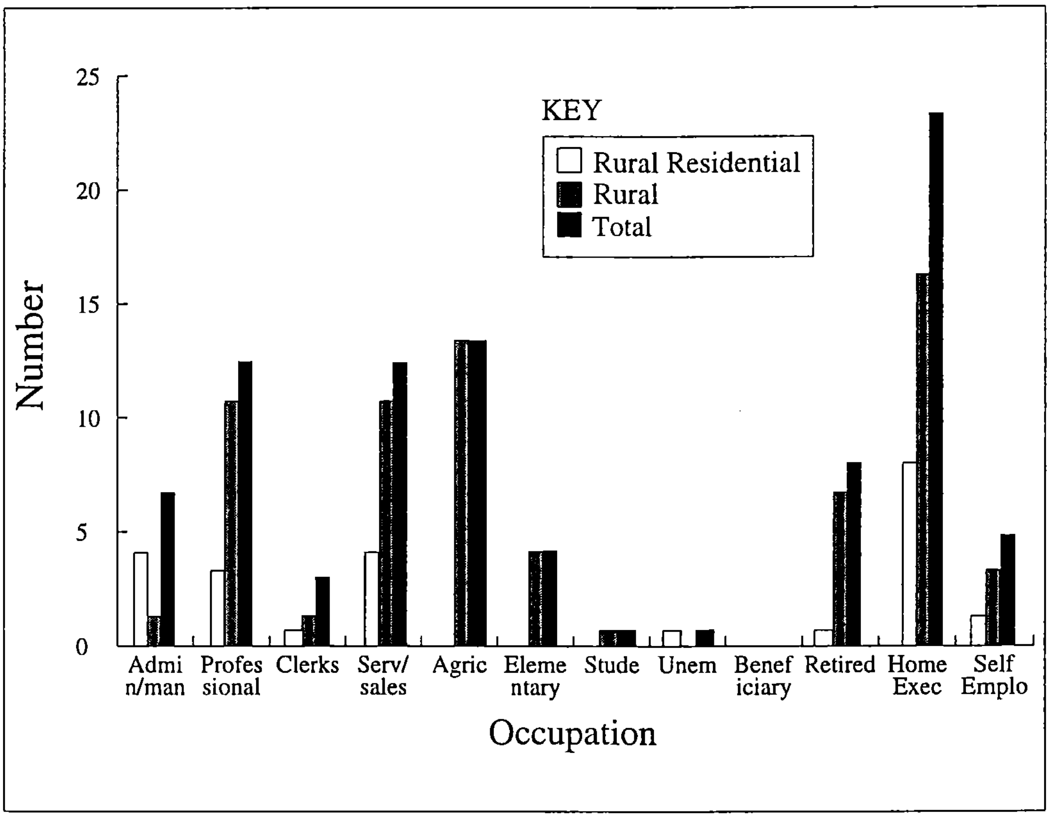
Figure 6.0: Ages of those surveyed in the field area



In the rural residential area 64% of the households consist of families of three or more, compared with the rural area which consists of more two person households. This reflects the ages of the residents and also the fact that younger people are moving into the rural subdivisions.

Rural residential subdivisions also have different occupational structures to those in the rural areas. Figure 6.1 shows the occupations of the residents in the field area. Of those surveyed the most common occupation was home executive on 23. This was followed by agriculture on 14 and professional, and sales and services on 12. In the rural area the most numerous occupations were in the home-executive (16), farming (13), services and sales (11), and professional (11) categories, these make up 72% of the occupations. This can be compared to the rural residential zone with its highest number being home executives on 7, followed by the administrative and management category with 4, and sales and services in 4 also. In the rural residential category 27% of respondents refused to answer this question. Most of the occupations are not on the land but are either in the Christchurch, Rangiora or Kaiapoi.

Figure 6.1: Occupation of those surveyed



These results show a diverse range of individuals who were surveyed. Ranging from Professionals to Farmers, and also a diverse age group. The answers to the following questions have been divided between rural and rural residential for the reasons stated above.

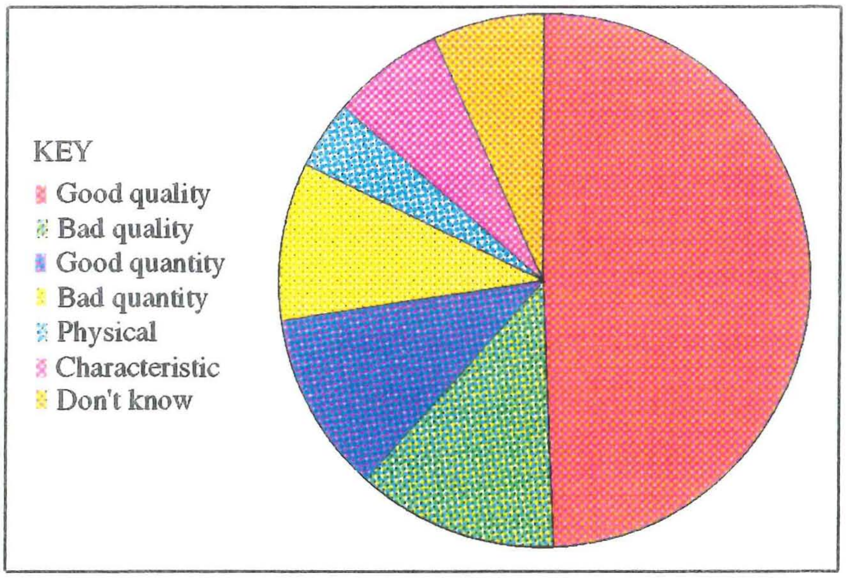
First Impressions

To gauge how, and what the residents felt about their groundwater supply they were asked an introductory question (what is the first word that came to mind when you think of your underground water supply?). This question is aimed at finding initial responses. The words were categorised into groups and the categories of responses of the rural community can be seen below in Figure 6.2.

Words that related to the 'Good quality' of the water were the most predominant answers at 50%, with words such as 'purity', 'clean' and 'fresh' in the rural community. The second most popular category at 12% was associated with the 'Bad quality' of the water with words such as 'cautious' 'safety'. This was followed closely by words that related to the 'Good quantity' of water (11%) such as 'lots of it' and 'abundant'. The category 'Bad quantity' of water at 9% had words such as 'run out' and 'is there enough'. Some residents were concerned with running out of water while others felt safe with their supply. This reflects the different locations of the residents. Some wells are susceptible to problems in times of low flows. The category 'Physical' (4%) implies a comment relating to the physical character of the water such as 'wet' or 'artesian' while 'Characteristic' (7%) was more of a general comment such as 'pump'. Don't Know was 7% of the responses.

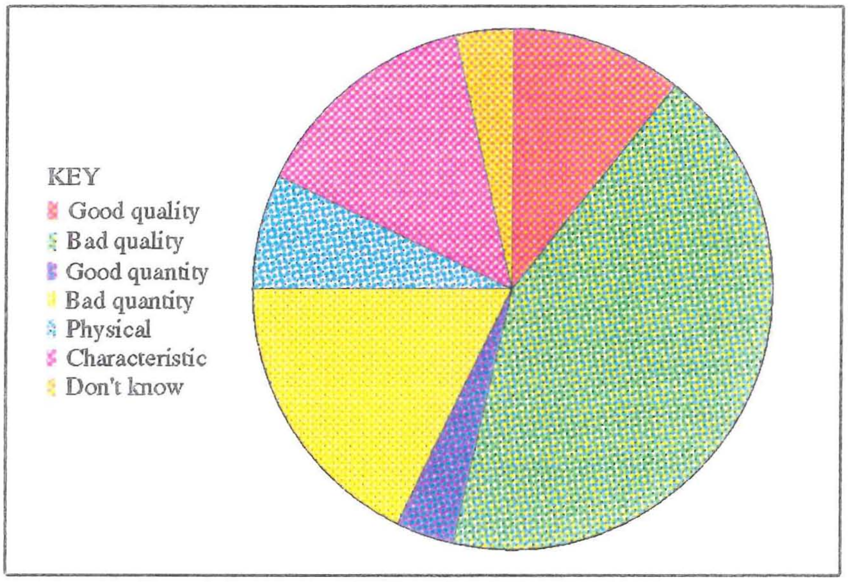
The response to this question shows that the quality of the water is important to these residents. 46% of 'professionals' answered that their their water was of good quality. While this was the answer of 57% of agricultural workers and 58% of home executives. The idea of good quality of water in Canterbury and New Zealand is ingrained into the minds and conscience of most residents, whether it is true or not.

Figure 6.2: Rural Communities, categorised first thoughts when asked about their underground water supply



The rural residential population when asked what the first word that came to mind when they thought of their underground water supply replied in a very different manner. The responses are below in Figure 6.3. The respondents most common answer at 43% was associated with the 'Bad quality' of the water. This however did not relate to the bacteria or the nitrates but to the chlorine. To the residents the chlorine was seen as a pollutant. The water was described as 'disgusting', 'awful' and 'absolute shit'. The next most popular answer relates to the low quantities of water that are available to the residents at 18% with comments such as 'water availability' and 'what water'

Figure 6.3: Rural Residential, categorised first thoughts when asked about underground water supply



The quantity of water was an important issue especially when they can not water their gardens on such dry land. The residents are on a restricted supply, and if on-site storage tanks are not on the property, then water is limited. The 'Characteristics' category was the third most popular response on 14% which included comments such as 'low pressure' and 'town supply'. Eleven percent of answers related to the 'Good quality' of the water, such as 'nice' and 'perfect' and 4% of the answers were in the 'Good quantity' section. These were generally the people who were not connected to the supply but used their own well. So even though they are in the rural residential zone they do not use the MWS. Seven percent of people related to the 'physical' nature of water, while 4% did not know what to say.

Water Condition

When asked to rate the condition of their underground water supply on a scale of one to five where one equals excellent and five equals very poor, the response of those surveyed is shown in Table 6.0 below. It can be seen that the majority of the rural community think that their water is excellent. At the 'poor' end of the continuum there was only 9% who did not think that their water was OK or better. This can be explained by a variety of reasons. Firstly, there is a perception that country water is clean and healthy.

Table 6.0: Perceptions of the condition of the underground water supply

	Rural Residential	Rural
excellent	0	55
good	29	20
OK	21	16
poor	25	6
very poor	25	3

Secondly, there is a lack of information on the quality of the water. Thirdly, they do not accept or care when they are told that the water is of poor quality. When talking with residents they said that they had been told that the water not pure but this did not concern them, and fourthly, because the residents have never been sick or ill from the water and it does not have an unpleasant smell or taste then it is regarded as being in good condition for consumption.

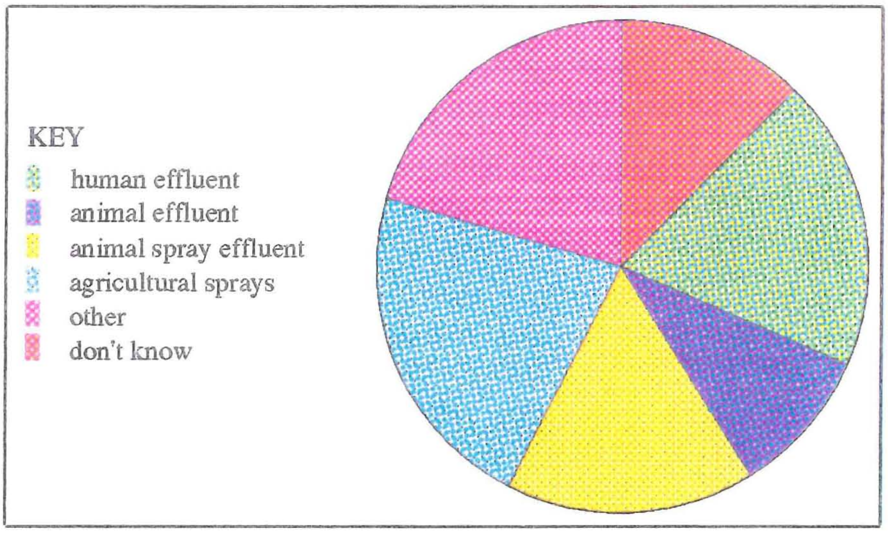
In comparison to the responses by the rural community the residential community had quite different responses. From Table 6.0 it can be seen that none of the residents in the rural residential zone thought their water was in excellent condition. There is a fairly even spread over the remaining scale. Twenty nine percent seeing the water as 'good'. Fifty percent however, felt the water was 'poor' or 'very poor'. This is a significant number, a fact that surely can not be ignored by the council. The water is unpleasant to drink, the "aesthetic constituents may make the water unpleasant to drink and effect the overall perceived quality of the water" (Sheat, 1992).

Inconsistencies were found between verbal and overt behaviour. For example one household told me what beautiful clean water they had, yet had installed a filter because of bacteria levels. The behaviour was to give the drinking water some form of treatment, yet the residents still deny that there is a problem with their water. An explanation of this may be that they have a degree of control over the risk so it is no longer seen as a risk. Or perhaps water that they receive after the filter is beautiful and clean. Because water quaity is based on aesthetic judgements such as smell, taste and colour (Ministry of Health, 1989), then the water would be perceived as being pure.

Sources of Pollution

There was a mixed response when the residents were asked who or what they thought the main source of pollution to the groundwater system was. This question was asked to see whether the residents had actually thought about how groundwater was polluted. The responses to this question can be seen in Figure 6.4.

Figure 6.4: Rural Perceptions of who or what the major polluters of the underground water are

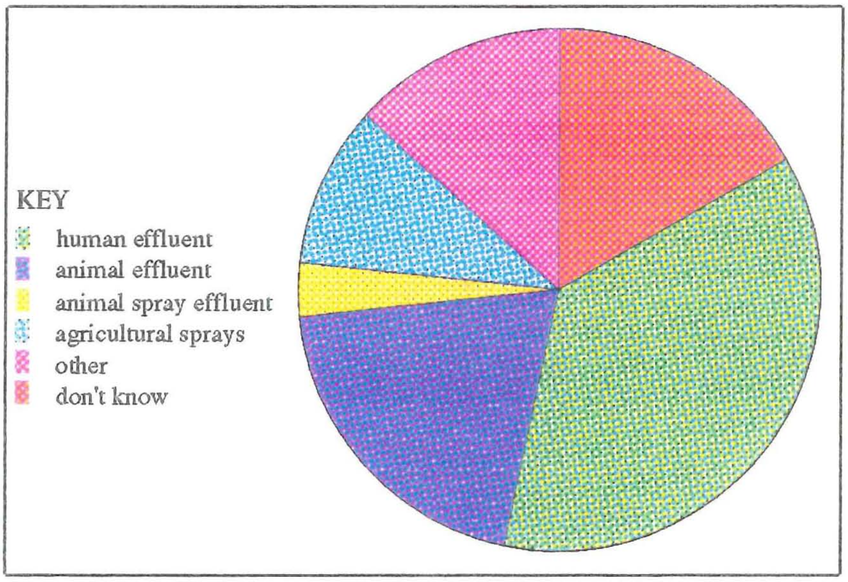


Twenty five people in total (24%) thought that the pollution was caused through human effluent, or the disposal of sewage. Responses such as 'it's all the housing development around here' were common. Twenty two percent of the rural community respondents thought that agricultural sprays were the main source of water pollution. This is a source that receives a lot of media attention. Nineteen percent thought that pollution was caused from 'human effluent', while 16% thought that spraying animal effluent on the ground was a cause for pollution. 'Other' scored 21% with contributors to pollution such as the 'dump', 'offal pits'

and 'chicken and turkey farms' being mentioned. The lowest response was from 'animal effluent'. This is rather ironic considering that it is cited as being one of the major contributors to nitrates and faecal coliform contamination on the plains (Sinton, 1986, Smith, 1993b, Hughes, 1993).

In the rural residential community 37% of the community felt that pollution was caused by human influences, this was predominantly septic tanks. This can be seen in Figure 6.5. Twenty percent thought that farm animals cause the pollution. Thirteen percent were in the 'other' category which included sources of pollution such as the 'dump' and 'Mandeville Sports Complex'. Ten percent thought that agricultural sprays and especially the orchards would have an influence on water

Figure 6.5: Rural residential perceptions of who or what the major polluters of the underground water were



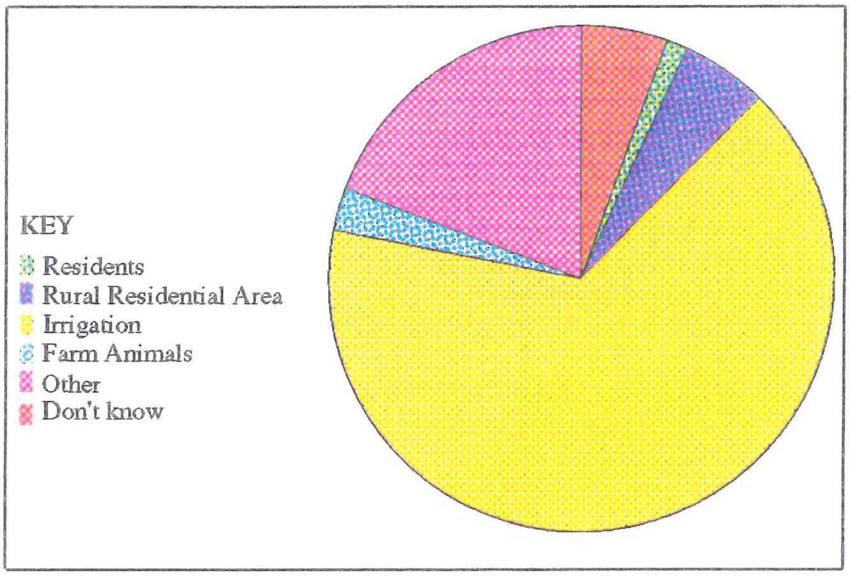
pollution. Seventeen percent of the residents did not have any idea what would cause the pollution, while 3% of the rural residential population thought that spraying animal effluent was a main cause of pollution. The residential community had quite a narrow focus mainly concentrating on what happens in their direct environment, and not looking beyond the subdivision. This can be compared to the rural community whose opinions were more widely distributed.

Water Consumption

The respondents were asked who they thought the biggest consumer of the

underground water' was. This was asked to gauge the residents awareness of who actually used the water. Figure 6.6 shows the responses for the rural community.

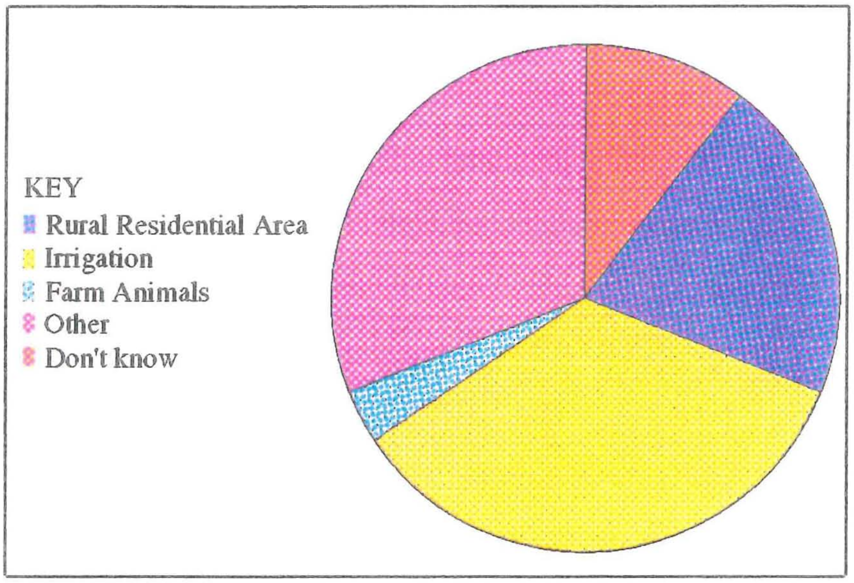
Figure 6.6: Rural perceptions of who or what is the biggest consumer of the underground water supply.



'Irrigation', at 65% was the most common answer to this question followed at 19% by the 'Other' which consisted predominantly with the response 'the orchards'. Equal on 6% was 'Don't know' and residents who felt that rural residential subdivisions were large consumers of water. Some 3% of respondents thought 'Farm animals' were large consumers and 1% of respondents felt residents, through domestic usage were the largest consumers of the water.

These responses compared to the rural residential replies shown in Figure 6.7 show that the most popular response to this question was also 'irrigation' at 35%. Twenty one percent of this group thought that the subdivision was a large consumer of water. Three percent thought that the 'Farm animals' were large consumers of water. Ten percent did not know who would consume the most water. These responses show that the respondents are aware of the uses of the water resource. The rural residential community gave more diverse responses to this question, as can be seen with the 31% 'Other' category. This consisted mainly of responses relating to 'orchards', but also comments such as 'the school' and 'Mandeville Sports Complex'.

Figure 6.7: Rural residential responses to who or what they felt was the biggest consumer of the underground water



Responsibilities and Preferences of water supply

The residents in the field area have different expectations, to what the role of the Council, with regards to water supply should be. When the residents were asked who they thought should be responsible for their water supplies; installation and monitoring' the response was very different, as Table 6.1 shows. This shows the gap between the expectations of those living in rural residential subdivisions and those living on larger blocks. This table shows that the rural population are willing to be a lot more responsible for the installation and monitoring of their water supply.

Table 6.1: Rural and Rural Residential opinions on responsibilities

	RURAL		RURAL RESIDENTIAL	
	Installation	Monitoring	Installation	Monitoring
Self	82	45	21	7
Developers	0	0	13	0
WDC	17	44	63	90
CRC	0	7	0	0
Independent body	1	4	0	0
Don't Know	0	0	3	3

Comparing this to the rural residential responses shown in Table 6.2, it can be seen that 63% of those surveyed felt that the WDC should be responsible for installing their water supply, Twenty one percent felt responsible themselves for the installation and only 13% thought that it should be the responsibility of the developers. This is another irony as it is the responsibility of the developers of a subdivision to provide a potable water supply.

As far as monitoring is concerned 90% of those surveyed in the residential community stated that it should be the responsibility of the WDC to monitor the water supply, while 7% thought it should be themselves. This is to be expected considering that the residents are on a reticulated supply that is controlled by the Council. In the rural area there was an even response to this question with 45% thinking it is their responsibility to monitor their water and 44% thinking it is the responsibility of the WDC. Even though these residents felt responsible for their installation over half (55%) of the residents surveyed, felt that another body should be responsible for monitoring the water quality.

Whether the community would rather be on a system that was controlled by the Council or by themselves was a question that was asked the residents. This was asked to see how satisfied the residents are with their present system, whether they prefer a community system like the MWS or a private well. The responses to this question can be seen below in Table 6.2.

Table 6.2: Preferences for a private well or a community system

	Rural Residential	Rural
Private	66	95
Public	34	5

It can be seen from this table, that the rural community have a far greater preference to be on private wells (95%), that is to stay with the source of water that they have at present, and 66% of the rural residential population would also prefer to be on a private supply. The rural residential respondents would prefer to be on private wells so they did not have such controls. Because the supply is restricted in quantity and the water is chlorinated, the residents feel they would prefer their own wells. The other 34% are content for the Council to have the responsibility for the water.

Survey Summary

The responses and perceptions relate to a variety of factors. At the broader scale they relate to a variety of characteristics such as; situational, personal, sociological and psychological characteristics. Situational characteristics can relate to the actual locations of a property. For example, a bore located close to a river will not have problems with high nitrates or bacteria, therefore the perception of those individuals will be that their water is of a high quality.

Personal characteristics relates to the background of an individual. An individual who has read a lot about water pollution, is highly educated, or lived in the area for a long time will have more knowledge about the quality of the water than an individual with little knowledge and is new to the area. Sociological characteristics relates to the values of the individuals. Psychological characteristics relates to the personal traits of the individuals and their attitudes.

At the local level the responses and perceptions relate to; awareness of the issue relating to the possibility of poor water quality, information availability, information access and interpretation of information and data. How much exposure an individual has had to knowledge of water quality is important to how they respond. The majority of rural respondents felt that their water was of good quality, yet are equally aware of how it can be polluted. One respondent however, was convinced that if elderly people or babies drank her water that they would be sick or die. Her water had been tested, and she had been told by the District Council's, EHO that this would happen. This resident gained knowledge from an authority on water quality and relied on his interpretation. Others who have had their water tested with similar results did not interpret them this way.

Judgements on water quality are not based solely on the content of the data, but also on how an individual chooses to interpret, or accept this information. An individual may choose to disregard the risk. If no information is available then the perceptions of the individuals will be what they have always thought or been told.

Members form the rural residential community tended to be more vocal about water quality. This group have obtained knowledge through communications with the council. There have been meetings between the community and the

Council regarding the water quality. Their concern with water quality is however with the perceived pollution from chlorination, and not from bacteria or nitrates.

The rural residential community felt more strongly because they feel they have no control over what they see as the hazard, and that preventative measures such as chlorination are more harmful to them. Hence, the 66% preference for having a private well. The group have many complaints about the water quality especially the smell and taste. People are bringing water from Christchurch, and are bathing and showering in Christchurch. There are complaints about skin rashes and blue stains that develop around the basins and showers. Because the impact of chlorination is prominent there is more of a 'dread' factor. Therefore, it is clear why the rural residents rate their water quality as being poor.

Consultation between the rural residential community and the Council has not been successful according to the residents. The residents feel that they are not being listened to, with their complaints being ignored and disregarded. When a meeting is called they are being told what will happen, it is a one way process. They feel that the decisions have already been made and talking with them is simply a formality.

6.3 Other Interested Parties and their Perceptions

Individuals were also interviewed from a variety of institutions connected to the management of land and water resources either directly or indirectly. Their perceptions were needed for comparison with the thoughts of the residents.

Ray Norris (Environmental Health Officer, WDC, 1994, *pers. comm.*) is concerned with the health and safety of the community so must respond to suggestions that the water is polluted. It is his opinion that the quality of water at Mandeville is 'terrible'. He insists on the necessity of the reticulated water supply at the residential subdivision. It is his opinion that people will get very sick if they drink the water untreated. The Management at the District Council reacts when there is a water problem in a community supply because bacteria is a high priority. Hence the start of the chlorination programme.

Ian Davies (Programme Engineer, Essential Services) at the WDC is responsible for the servicing of rural subdivisions if they are under the control of the council.

When asked whether he thought the water was polluted, replied that he does not know "but there is a rumour from the EHO that the answer is yes" (I, Davies, Programme Engineer, Essential Services, WDC, *pers. comm.)*. The action he took by installing the chlorination system was because he was "running on a gut feeling, that yes it was polluted". Ian Davies wants safe drinking water in the district and that may mean the installation of public water supplies to more areas.

Leo Fietje is the Consents Officer and previously the Investigating Officer at the CRC. He gave evidence as an Objector to the rezoning of the 86.8 hectare block of land at Mandeville because of the proposed disposal of effluent via on-site septic tanks. His comments on the background water quality were, "this water is variable but generally poor, with nitrate concentrations approaching and sometimes exceeding the NZ Department of Health recommended standard for drinking water" (Fietje, 1991a:2). When asked whether he thought that there is a pollution problem his response was, "Yes I do, there is a problem particularly in this area between the Ashley and the Waimak. Mainly from faecal coliforms and secondary chemicals such as Nitrates and household bleaches" (L. Fietje, Consents Officer, CRC, 1994, *pers. comm.*). His perceptions are based on results from the sampling programme that is undertaken by the CRC.

Vivian Smith a Water Quality Officer at the CRC felt the same, but indicates that generalisations can not be made on present data. Unless a comprehensive testing programme is undertaken then there is insufficient evidence. She stated that the problem is predominantly from non-point sources, and that there are also problems from septic tank effluent. With regards to the disposal of sewage Ms Smith feels that "There is a lack of education in relation to septic tanks, and how to deal with them" (V. Smith, Water Quality Officer, CRC, 1994, *pers. comm*).

Dianne Morrison of Health Link South (HLS) feels there is a real threat to human health because of water quality, especially in relation to septic tank effluent. It is HLS's policy to, "make a leap to reticulate if an area is going to progress... do it properly now so there is not a problem later" (D. Morrison, Health Officer, HLS, 1994, *pers. comm.*). HLS are very vocal when an area is subdivided because of the threat to human health that effluent can pose.

Lester Sinton is a Microbiological Technician at Environmental Science and Research (ESR) and has done a lot of research on the impact of microbial contamination on groundwater. He acknowledged that the stonier the gravel the more susceptible the water is to pollution. He compared the area to areas studied in Burnham and Yaldhurst. It is his opinion that, "shallow groundwater can not be used as a sewer and used for good water, you must have one of the two things,... you could drill deeper and sacrifice the top aquifer" (L. Sinton, Microbiological Technician, ESR, 1994, *pers. comm.*). This double use is what is occurring at Mandeville. With the absence of a deeper aquifer this is not an option.

Murry Close also a technician at ESR commented that the groundwater quality in North Canterbury is, "fairly good". He went on to add, "in shallow groundwater you expect bugs and nitrates below 10-15 metres, below 30 metres is fine" (M. Close, Chemistry Technician, ESR, 1994, *pers. comm.*). This area below 10-15 metres is where all the wells in the field area are located.

All of those interviewed acknowledged that there is a problem, but did not have the facts to back it up, nor did they know the extent of the problem. Most of the responses were educated guesses. Their knowledge and perceptions came from comparative studies, what they had heard or been told, or their own deduction. Like the information that the public receive (if any), there is no verification or clarification that a problem exists. The WDC has established a database on water quality in their district so as they can establish the extent of the problem. This however will only give results at particular times and places that can not be readily compared to other results. A thorough water quality testing programme is needed to establish exactly what is occurring under certain conditions. If the database reveals that there are consistently high bacteria counts then planners must respond, and action taken. Water quality problems are not seen as a tool to stopping development according to Ian Davies (WDC, 1994, *pers. comm*) but it may be a consequence. Preventing development will not cure the existing problems.

The planners and managers, while acting on "gut feelings" at present, find it difficult to prevent development, because they can not prove that development is having a detrimental effect on the environment, or that residents have to be protected from the water supply. In April 1993 the WDC did establish a policy that states that when a subdivision is proposed it must include a reticulated sewer system.

6.4 Why do residents and 'experts' see things differently?

Why is there such a difference between what the individuals surveyed thought and the expert opinions about the field area? There are two contradictions apparent. The first is the difference of opinions as to whether or not the water is polluted, and the second concerns the conflict over the use of chlorination in the Mandeville Water Supply, with the residents surveyed feeling it is not necessary and the Council saying it is. In the first contradiction, the public perception is that there is no riskto their health from pollution, while the council feels there is a risk. In the second conflict the Council perceives there to be no risk or annoyance through chlorination while the residents feel there is. The rural residential population felt there more risk from chlorination than bacteria.

Fischhoff *et al* (1981), lists six reasons why expert and community risk estimates differ and why risk conflicts occur. They are that:

(1) the distinction between 'actual' and 'perceived' risk is misconceived,
(2) lay people and experts are talking different languages,
(3) lay people and experts are solving different problems,
(4) debates over substance may disguise battles over form,
(5) lay people and experts may disagree over what is feasible, and
(6) lay people and experts see the facts differently.

While the individuals are looking after themselves and the needs of their household, the Council must take into consideration wider issues such as the health of the entire community. This however is not a consideration of the individuals who feel their ideas are not taken seriously.

There is the need for a "two-way' process (Gough, 1991). Public input whether it be complaints, comments or perceptions should not be seen as a nuisance but as a benefit. If there is public discord over an issue, it can be very difficult for a decision to be made and action to be taken. The Council needs to approach the issue differently. Instead of in-house decisions with token gesture meetings, there needs to be a concerted effort for "two-way" communication. Conflict will continue unless both parties are satisfied with negotiations and communication methods. Marjorie Shovlin, a water quality specialist in California states "Without public support, and in many cases with public opposition utilities can not move ahead... the participation process eventually gains the public trust, so that when water supply authorities make a decision the public is not as likely to oppose it" (Thompson, 1992). If the public feel they are being ignored then this will escalate the problem.

"The key feature of effective communication is that it should be a genuine effort to involve all parties for the purpose of resolving an issue" (Gough, 1991:5). Joan Dent, public information director for the American Water Works Association (AWWA) says that the "shift is away from keeping the issue of water quality a federal or utility providence, toward keeping the decision more community based" (Thompson, 1992).

6.5 Rural Residential Living

Ideas of country living (the rural idyll), are not living up to the expectations of the rural residential 'lifestylers'. A study done in the Waimakariri District in 1991 (WDC, 1991) of 13 rural residential areas show that 46% of residents came from Christchurch. It can be seen that a high proportion of these rural residential 'lifestylers' have been used to city living. Their expectations of services that are provided to them are very high. An image of country living to city dwellers and what it entails is a lot different to what it is in reality. They expect a country outlook, a safe, healthy and clean environment (WDC, 1991). They are disappointed if they do not received this.

The Waimakariri District Council study (1991), also showed that 53% of those surveyed were motivated into rural living because of the rural environment. Space, peace and quiet were popular reasons chosen, others included rural scenery, fresh air, security and room for animals. Lifestyle was the next reason for moving at 26% and this involved "healthier living", "more relaxed" and opportunity for activities such as gardening.

Many residents at the rural residential subdivision at Mandeville are "disillusioned". Water is limited and of poor quality, and to them this is not acceptable. Comments range from complaints about not being able to water the garden, "it is more private in town", the long distance to schools and friends in town, and the time involved in maintaining the property, mowing lawns and feeding the animals. Lifestyle blocks have certain criteria for the owners, and if the property does not live up to these they will leave. The turnover in the rural residential subdivision is very high. One property has been bought and sold three times during 1994.

Leo Fietje of the CRC was surprised to hear of the disillusioned nature of the residents (Leo Fietje, Consents Officer, CRC, 1994, *pers. comm.*). When discussing rural residential living Leo Fietje stated that "so long as people want it, (rural residential subdivisions) it makes for healthy living" (ibid). This healthy living is disputable. People may think that they want to live in the 'country' but when they see what it entails or it is not what they expected, they will move back into town. There is however, the intention to increase the amount of rural residential subdivisions in this area.

Decision-makers have an obligation to take into account the needs of the community. Some residents are dissatisfied with the essential services that are being provided, and the quality of life that they are living. Is this the fault of the District Council, for allowing a subdivision, or is it the workings of the new hands-off policy in which everyone, including the public, developers and councils must now operate under, which allows sporadic development? If the council is going to take into account the opinions of future residents in a community, it must take into account the conditions in which the residents are living at present.

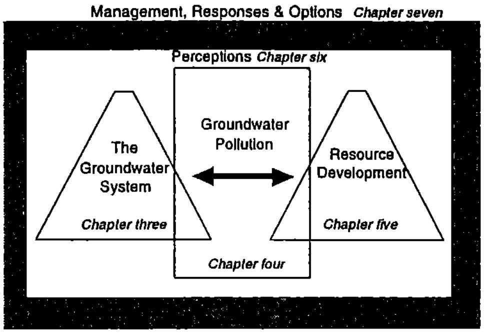
6.6 Summary

This chapter has endeavoured to show the opinions of the residents in the field area and the other interested parties. The surveyed residents in the rural community and rural residential community have differing opinions, in that the rural community perceive their water as being of high quality, 55% thought that it was excellent, while the none of the rural residential individuals surveyed thought that their water was excellent. Comparing this to the opinions of the 'experts', it can be seen that while they thought that there was a potential problem with the water quality only the EHO at the WDC was willing to state this openly.

By discussing the perceptions of the rural idyll and the study undertaken by the WDC (1991), it can be seen how the water quality debate is a part of the overall disillusioned nature of residents in the rural residential subdivision. The qualities of rural living to which the residents aspire, are not being fulfilled.

This chapter has highlighted the fact that there are a wide variety of perceptions relating to the quality of groundwater. It has shown that while no one is aware of the extent of the groundwater quality problem, almost everyone has an opinion. As Thompson (1992), states "perception may very well become more important than reality...especially when it comes to the quality of drinking water" as it is perceptions that are acted upon when facts are erroneous. "Perception of hazard risks and adjustments are fundamental components of adjustment choice and risk mitigation" (Saarinen, 1984:3).

Chapter seven goes on to discuss the various responses and adjustments to the hazard of water pollution, by individuals, local authorities and central government. It endeavours to provide an understanding of what is occurring at present and what the various options for management are in the future.



CHAPTER SEVEN

Management, Responses & Options

In the introduction to this thesis a model was presented (Figure 1.4). This led the reader through the important components of the topic. Being based on hazard literature, it described the physical system, the human use of the land, and their interactions with respect to water resources and hazards, Different perceptions of those involved with water quality in the study area have also been discussed. An assessment of the responses to the hazard is necessary to see how, and why the resources are managed the way they are, in relation to perceptions.

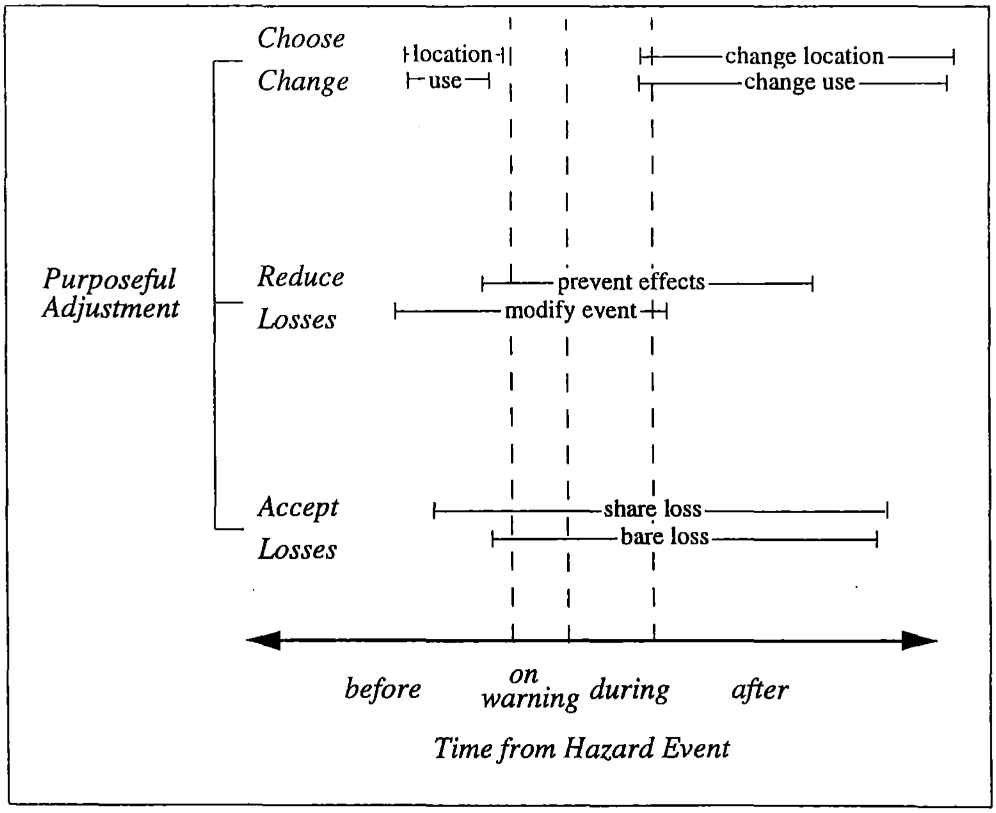
It is important to note the nature of water pollution, and how it is expressed through the different components set out in the model. All components in Figure 1.4 while looked at individually, are part of a system that works interactively. To be successful, management of resources must be done in a way that looks at components individually but also takes account of how the individual units belong to this system. As Gestalt philosophy states 'the whole is greater that the sum of the parts'. An understanding of the whole system is essential.

Chapter seven discusses the various responses to the problem of water pollution in the field area including how it is managed at present and options for management in the future. Responses to water pollution and its causes and effects have occurred at many levels. At the applied level for example, responses can be seen from an individual installing a water filter to the District Council chlorinating a public water supply. With the enactment of the RMA in 1991, law was developed that gave national and local authorities duties and functions pertaining to the management of natural and physical resources. Examples relating to water pollution are; s9 the use of land, s14 restrictions relating to water, and s15 rules for the discharge of contaminants into the environment. Legislation such as the Health Act 1956 has also led to responses to water pollution because of the public health implications. "Response to hazards is related to perception of the phenomena themselves and to an awareness of opportunities to make adjustments" (Burton, Kates and White, 1978:34).

7.0 'Adjustment to Hazard'

The term 'Adjustment to hazard' has been adopted by Burton, Kates and White (1978). This term relates to the various responses that can be made by decision-makers in the presence of a hazard. "This adjustment begins with an initial choice of a resource use, livelihood system and location" according to Burton, Kates and White (1978:46). In the field area this relates to the choice to live in Mandeville, as either a farmer, or on a section as a lifestyle block, and to use the groundwater resource. With this initial choice made, when and if an individual or organisation recognises a threat or potential hazard then there are a variety of purposeful adjustment options that may be taken. Figure 7.0 shows these, and how they are set within a temporal context. Adjustments can occur anywhere from before the hazard occurs, through to responses after a hazard event.

Figure 7.0: Choice Tree of Adjustments to Hazards



After: Burton, Kates and White, 1978

There are broad choices available to all decision-makers in the form of purposeful adjustments these include the ability to; choose a change in the resource use or change of location away from the impact of the hazard, another choice is to, reduce losses, by using preventative measures, or to accept losses, by bearing the burden of damage to property or ill-health. The most radical choice is to change the original use or location.

Choices involved with hazard adjustment also involve the matter of when adjustments should be made. There are reactive measures that can be taken after the hazard is detected or impacts felt, or preventative measures. Another choice concerns what should be adjusted, the physical processes system or the human use system? An example of adjustment is modification of water pollution hazard through water treatment by the District Council. This is a reactive adjustment as the hazard is modified by treatment before it can affect the public.

An alternative response is to modify the human use system. This could involve not locating residences in the hazardous area. Preventative measures are an option, for example adopting adjustments that affect the cause, such as Land Management Plans that take into account the landuse on the Plains. While landuse consents are needed for many activities on the land, general farming, with cattle and sheep grazing, are a real problem for groundwater quality. By using such measures as discharge standards for septic tanks, it is possible to control pollution entering the groundwater system. An option that is available to individuals is to adapt to the loss by accepting the loss of water quality. This however is not an option for the public supplies where maintaining a potable water supply is essential.

These various adjustments are shown in Figure 7.1, which presents a model that has been adapted from the model Figure 2.3 introduced in chapter two. This shows the various options that can be adopted at different stages of resource use. The various adjustments that can be taken include:

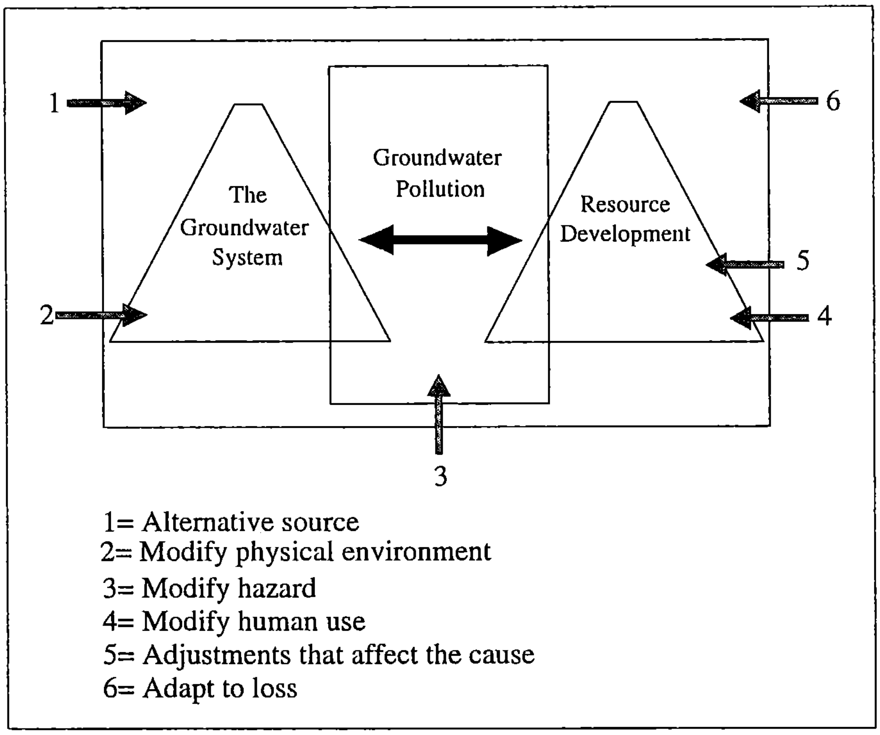
1) *Choosing an alternative source* of water,
2) *Modifying the physical environment.* (This is some form of adjustment to the groundwater system which is difficult to achieve because of the nature of groundwater),
3) *Modifying the hazard* can be achieved through water treatment,
4) *Modifying the human use system* may involve changes in landuse,

5) *Adjustments that affect the cause*, could be some form of policy to prevent discharges, and

6) *Adaption to the loss* of water quality.

The responses taken by individuals and local authorities in the field area will be discussed in the context of this model below (Figure 7.1).

Figure 7.1: Responses at various stages of resource use



Source: Author, 1994

7.1 Individual Responses to pollution in the field area

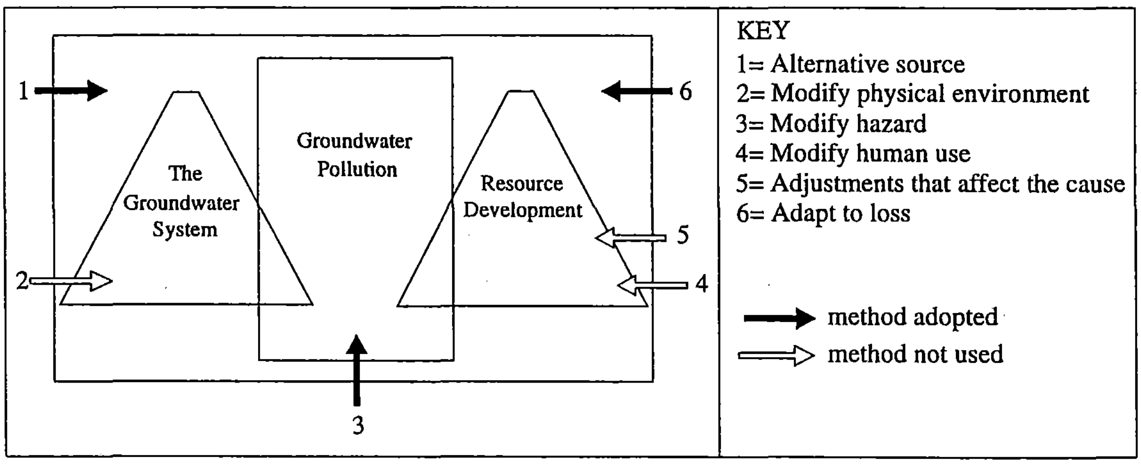
Response requires that there first must be an awareness or acceptance, that there is a problem. Various adjustments of individuals were gathered while in the field area. The majority of the rural community was of the opinion that there is no problem with the quality of the water. Therefore, there is no response. After having received water test results, which show high bacteriological rates, some residents however, have chosen to seek some form of mitigation, in the form of modifying the hazard.

One resident installed a water filter and aerator 14 years ago. This installation was prompted by the death of poultry on the property, due to high bacteria counts. One household after 18 months of trying for potable water, (needed because of the wish to subdivide) use UV light in combination with a water filter. This has produced potable water. While this satisfies the District Council the owner is still not satisfied because not all of the water in the house needs treating (only the drinking water). There is another resident using UV light treatment because of the presence of bacteria in the water. Yet another resident boils the water before drinking it.

In the rural residential area other responses are evident. In response to the chlorination of the water supply water is brought from Christchurch in bottles, for both drinking and washing, thereby using an alternative water source. Others spoken to had showers and baths at the homes of relations in Christchurch. Filters have been installed for drinking water in three of the households to reduce the smell and taste.

These individual responses are prompted by a concern for the quality of the water supply and, consequent perceived implications for the health of family members. Individuals are responsible for the quality of their water, if it is from a private well. It is, therefore, their responsibility to treat the water so it is potable. Many residents however chose to do nothing, because they have always drunk the water and have never been ill. Figure 7.2 shows the responses that are adopted by individuals in the study area.

Figure 7.2 Individual responses to groundwater pollution



The majority of these responses (with respect to hazard literature) are 'adapting to the loss'. Residents in this category either do not have a problem, or are choosing not to respond. Most of the respondents who feel there is a water quality problem, 'modify the hazard' by treating the pollution with a filter, UV light or by boiling the drinking water. There is a minority of residents who use an alternative source out of the local area.

Individuals do not have the power or the resources to mitigate in any other way. Therefore their responses are usually reactive. The district councils however have the power to use a wider variety of adjustments to prevent or cure the groundwater pollution problem.

7.2 District Council and their response to groundwater pollution

"The Vision for 2020" is a document "setting goals for the future, encouraging community foresight, and developing wisdom in planning" according to Trevor Inch, Mayor of the WDC (WDC, 1993). The District sees protecting and enhancing the water resource as being an important part in achieving this vision. There is the realisation by the Council that "the ability of the district to grow and prosper is, first and foremost, dependent on the quality of its groundwater" (WDC, 1993:10), therefore its protection is essential. This vision in combination with others, make up the objectives of the WDC and there long term aims and strategies, so as snap-shot decision-making is avoided.

These visions will go towards achieving the summary statement wish expressed in "The Vision for 2020" document that "The people of the Waimakariri District will enjoy high quality natural, living and productive environments and a distinctive sense of community" (*ibid*). However snap-shot decision-making is still occurring at present. According to L. Woudberg (Planner, Waimkariri District Council, 1994, *pers. comm.*) it will be "another 10 - 15 years until we see a change of way things are done.....people have still got their blinkers on... with consents being granted in an ad hoc fashion".

The issue of water quality in the study area, has shifted from being a physical phenomena to becoming a political issue. The matter of water quality in the field area was not politicised in the past. It was not openly discussed in the public arena. It is only over time, with an increase in population in the District (demanding potable water), an emphasis on environmental quality under the

RMA, and the role of consultation where issues are discussed in a more open manner, that the issue of use and abuse of the groundwater resource, and its potential pollution has developed.

The District Council approaches the water issue, from the viewpoint of public health. Under the Health Act, "it is the duty of every local authority to promote and conserve the public health within its district". If there is a condition or nuisance that is likely to be injurious to the health of the residents then it is the duty of the district council "to cause all proper steps to be taken to secure the abatement of the nuisance or the removal of the condition" (Health Act 1956, s23).

Public health however, is not the only reason of concern by the District Council. With sporadic development occurring in the District, it is essential for the Council to uphold the quality of essential services, and ensure the protection of the groundwater resource. The Council feel they are "reacting to development not guiding it" (James, 1993:8). The Council has no doubt that there is "an urgent need to develop sustainable resource management plans to guide all types of rural development" (*ibid*). Subdivision policy at present is in a "void" a "vacuum" because of the transitionary nature of the Plans from the Town and Country Planning Act 1977 to RMA (L. Woudberg, Planner, WDC, 1994, *pers. comm.*).

The Council has a role to ensure the water quality of existing wells, so that discharges from housing development must be controlled. The Council must also ensure that new developments have water quality that meet the New Zealand drinking water standards. The responsibility for establishing the services such as power, water and sewage disposal, in the case of rural residential developments are the developers, usually as part of the conditions for developing the land. The responsibility for the sewage and water in a rural residential development is usually transferred to the District Council. It is, therefore, in the interests of the District Council to have services that will not be costly and difficult to operate and maintain. With an increasing rural population it is essential that the groundwater resource is protected because of its role as drinking water and that sewage is not threatening this resource.

Because of the Health Act, and the importance of public health, and the potential threat of poorly established essential services, the District Council must establish ways to both manage subdivision, as well as ensure the provision of adequate services to the area, without causing adverse effects on the environment. Several methods have been used to achieve this. In relation to the health of the residents, the Council has established a rule in the Transitional District Plan, that when subdivision is sought on a property there must be the provision of a potable water supply. This ensures that all new residencies have potable, safe water supply. It is also the responsibility of the District Council to administer the Building Act 1991. Under this Act, when a building permit is sought, it is necessary to have potable water supply at the time of the proposal and 18 months after completion. These are the rules for private wells and developments.

It is also important that a public supply is potable. The District Council has stated that the "protection of existing public water supplies is a top priority" (WDC, 1993). The WDC requires a community water supply when ten or more new lots are developed. When the Mandeville subdivision was developed a reticulated water supply was established to supply water to the residents. Because of the importance of water quality the maintenance and monitoring of this system was transferred to the WDC. This system has been chlorinated since 1991. This response to water pollution by the Council, is similar to that of the individuals, that is, to 'modify the hazard' by treating it.

Two zoning methods adopted are groundwater protection zones and effluent plumes. Groundwater protection zones are located upstream of water supplies, (both private and public). The zone for public supplies whose groundwater is less than 70 metres deep, consists of an area one kilometre upstream and 200 metres in every other direction (as shown in the example in Appendix 8). This zone ensures that no new effluent system is installed within the protection areas. This method limits development between subdivisions

An effluent plume is the zone surrounding an effluent disposal system, or any type of discharge, (Barber, *et al* 1991) where groundwater is affected or potentially affected by the discharge. It is usually a teardrop shape extending in the direction of the groundwater flow. The effluent plume is determined by the characteristics of the discharge and the groundwater characteristcs such as flow and velocity. The effluent plume should not enter a groundwater protection zone. These two zoning methods are restricted to new developments since existing development typically would be exempt as a result of being prior nonconforming uses. Therefore alternative measures are needed in areas where the protection zones and effluent plumes overlap.

Sewage as a threat to water quality

With the proposal of a subdivision of 86 hectares for rural residential living upstream of the Mandeville subdivision, the Council have proactive methods to respond to a perceived potential pollution threat. Under the RMA, the duties of the District Council (these can be seen in Appendix 9), extend further than simply treating the hazard. They are able to control uses on the land that have adverse effects, by having rules in a district plan. Because of their role as the consent authority for the subdivision of land, they are able to refuse subdivision on a variety of grounds (stated in s406 of the RMA, in Appendix 10), if it does not allow for adequate disposal of sewage (which can be a major pollutant to the groundwater), or if it is not the best practicable option (RMA s108(1)(e)).

However, in the case of the proposed subdivision, to refuse subdivision consent under s406, would require technical evidence to back up concerns about sewage disposal. This may be difficult to do, and expensive, given the volume of technical expertise bought to bear in support of the sand filter (as a means of disposing sewage), by the Regional Council. There has also been a development of case law established through previous Planning Tribunal decisions that support the use of the sand filter.

This development will pose a threat to the Mandeville Water Supply. In order to protect this supply, sewage discharge must be restricted upstream of this well, as there are no absolute guarantees that there will be no effects from sewage discharges. However an option is to relocate the water supply so it is not downstream of sewage discharges.

Sewage in high concentrations can be a threat to groundwater. Both the Regional and District Councils are involved in sewage disposal. However they administer different Acts of Parliament and therefore have different functions. The Regional Council assesses the impacts of sewerage discharge on the environment and decides what conditions are necessary to protect it. The regional councils also administer the General Authorisation for septic tank effluent disposal and treatment, and gives consent for discharges. Under s22 of the Water and Soil Conservation Act 1967, the CRC authorises the discharge of sewage tank effluent into ground. A Regional Rule for this discharge is given status by the RMA and is part of Regional Plan. This rule for on-site sewage disposal states that;

- the daily volume discharged must not exceed the maximum allowed for the size of the property,
- sewage must be treated to a minimum standard (unless groundwater is less than 30 metres deep),
- minimum separation distances must be maintained from surrounding bores,
- the disposal system must be at least 20 metres from surface water,
- specific requirements must be made for subdivisions

(CRC, 1994).

If these cannot be met, a discharge permit application is required.

The district council administers the Building Act 1991 and makes sure the septic tank system including all the drains and pipe work, does not pose a risk to human health.

The gap between decision-making and implementation

Conflicts arising over the management regime with regards to effluent discharge evolve when one authority (regional council) is providing standards and giving consent to the systems that are used. Yet if this system fails for either technical reasons or that the system does not suit the environment, it is the responsibility of another authority (the district council) to repair or replace the system once they have assumed responsibility. The district council should have initial input if they are to be responsible for the system. An example of this occurring was afailure of a system in a subdivision in Ohoka. After being approved by the Canterbury Regional Council and objected to by the Waimakariri District Council. Inappropriate technology had been used on the site, and for the site conditions, and when the area was flooded with sewage it was the responsibility of the District Council to solve the problem. An issue here is who has responsibility when a system fails and who pays for the repair? When a District Council takes over a system it wants to ensure that it is the best possible option for the site and the local conditions. It is the opinion of Dianne Morrison, (Health Officer, Health Link South, 1994, *pers. comm.*) that if the District Council allows subdivision they must accept responsibility for that subdivision .

Because a development may have a detrimental effect on the environment, or it may endanger the integrity of existing water supplies, the method of controlling subdivision is an option that is regarded in terms of hazard literature as an 'Adjustment that affects the cause'. By not allowing subdivision of land, or requiring consent conditions that mitigate the effects of the sewage disposal, there is no extra sewage added to the groundwater system. However, the RMA makes it difficult for the District Council to restrict developments without showing that such developments are having an adverse affect on the environment.

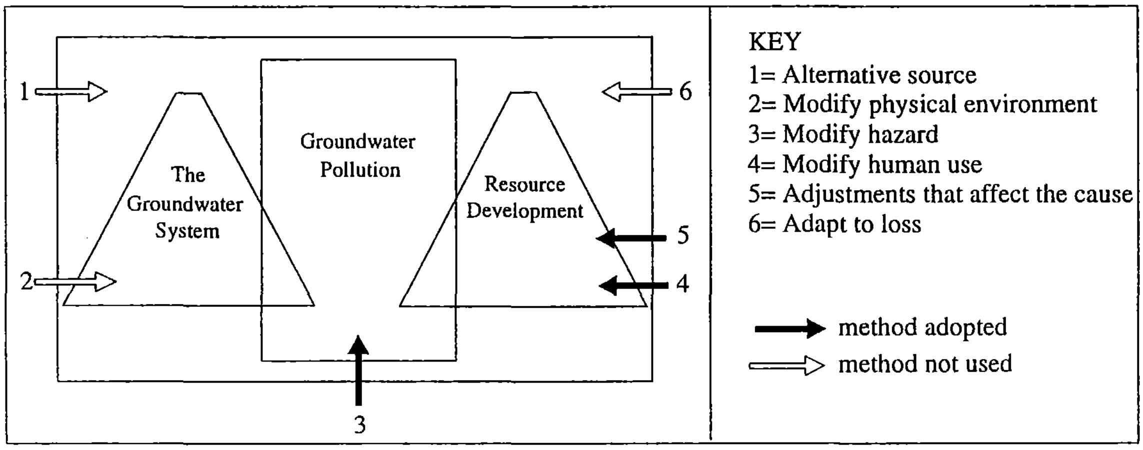
Rules relating to individual septic tanks

Individual septic tanks are permitted activities. On application for a building consent the district council checks that the system complies with conditions. All new septic tank discharges need to comply with the new standards of 1000 faecal coliforms per 100 ml sample by the time the discharge reaches the groundwater. If a discharge fails a resource consent must be obtained to discharge contaminants. Old systems do not have to comply with these standards until they are modified, repaired or extended. Often because of the cost of compliance, for a resident that has a system that needs maintainance, either maintainance is ignored or changes are made without notifying the council.

Rules applying to septic tanks are preventative in that their aim is to make an adjustment that affects the cause of pollution, but the old tanks that prevalent in the field area and Canterbury are still polluting the groundwater. So who is responsible for the pollution from these tanks? The District under the Health Act, Building Act and the RMA or the Regional Council under the RMA if the problem caused by failing systems is regionally significant?

The various responses chosen by the District Council can be seen below in Figure 7.3. The responses are a combination or reactive and proactive responses, that consist of measures that prevent groundwater pollution such as landuse and subdivision rules, and modifications of the hazard via water treatment. Future options for the Council include the possibility of utilising an alternative source and having the District on a reticulated water supply.

Figure 7.3: District Councils responses to groundwater pollution



7.3 Regional Council, and their response to groundwater pollution.

The Regional Council's functions, powers and duties are stated in section 30 of the RMA. The relevant parts in relation to groundwater pollution are found in Appendix 11.

Water is a protected resource under the RMA and can only be taken or used with the consent of the regional council. It is recognised that water is a regionally significant resource so it must be managed and monitored at the regional level. The regional council collects background readings of the groundwater quality at certain sampling locations around Canterbury as was discussed in Chapter 4. Unless a specific problem is identified, such as leachates from a waste disposal site no specific sampling programmes will be undertaken.

Policies and methods used to achieve water quality

The Canterbury Regional Council has responsibility for water quality under the RMA. Their objective in regards to water quality is to protect the natural character, value for mahinga kai, cultural integrity, and life supporting capacity, and to control discharges of contamination into water, either directly or via land.

Policies to achieve this include:

1) establishing water quality standards

2) controlling discharges and land uses to maintain quality
3) promote maintenance and enhancement of quality

The use and setting of standards is in the past has generally been a response to an actual or perceived problem. Under the RMA the environmental standards aim to be preventative, a "mechanism to define environmental outcomes" (Slater, 1992:2). An important attribute of standards is that they generally have a basis in empirical studies on cause and effect. The socially determined element of environmental standards represent a minimum requirement or a specific target for environmental management.

Because of the finite capacity of water to assimilate contaminants, controlling discharges and land uses to maintain quality essential. Landuse consents and discharge permits are required if there will be significant effect on water. The use of economic instruments and cost recovery are also used to achieve the objective of maintaining and enhancing the water quality.

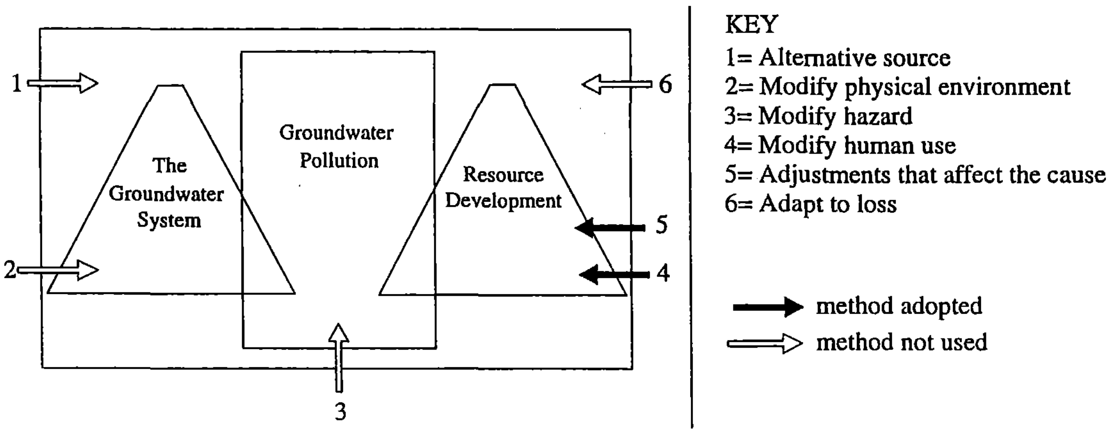
An economic instrument is a resource management tool. It is the use of the market and price mechanisms to assist in the implementation of environmental policy. This follows the approach to let the market be the decision-maker on how to distribute resources. Economic instruments are aimed at modifying behaviour and using private incentives to achieve this modification. Uses in water quality management include tradeable permits and the use of the polluter pays principle. Examples of both national and international success stories with the use of economic instruments are found in Higgins (1991:21). Limitations are however apparent with identifying polluters and the actual cause of non-point source pollution. A. Meister a Massey University Professor reported that "Agriculture is one of the leading culprits" (Higgins, 1991:20).

Four general strategies for achieving agricultural non-point source pollution abatement suggested by Meister are; a tax to discourage run-off; estimated run-off standards; economic incentives for farm management practices and the setting of farm management practice standards. Economic incentives for farm management practices (such as nutrient taxes) were considered to outperform the other strategies according to Meister (Higgins, 1991:22).

These objectives are also achieved by undertaking water investigations. These are undertaken to assess the quality, flows and volumes of the water. At present a study is underway by the CRC that is assessing the impact that small unsewered communities in the region are having on the groundwater system and general water quality in the region. With a prolific amount of rural and semi-rural communities in the region the impacts from these developments could have regional ramifications and are therefore a regional issue. This type of study is a response to a potential problem, it will assess the extent of water pollution (if any), and provide some form of solution. The importance of investigations is to establish facts or at least the most likely scenarios of what is occurring in an area. This information leads to greater knowledge, and more accurate decision-making.

The last policy of the CRC concerning water quality is the promotion of maintenance and enhancement of quality. This is achieved through the provision of information and education. This is a preventative measure that is aimed at adjusting the way in which humans think. An increase in education and awareness in the community on issues relating to water quality would lead to a more knowledgeable population. In relation to causative effects and compliance with septic tank effluent "In most cases home owners won't even realise that the rule exists" (CRC, 1994:2). Is this a desirable thing? If the population is more aware of the susceptibility of the groundwater to pollution and the causes of this pollution then surely this is beneficial. Figure 7.4 below shows preventative measures adopted by the Regional Council as methods used to prevent groundwater pollution.

Figure 7.4: Responses adopted by the Regional Council



Regionally Significant Groundwater Pollution?

In the field area the major source of pollution which can be regarded as a regional issue and therefore, regionally significant (even though this term 'regionally significant' is very value ridden) is non-point source pollution. Nitrates and coliforms from animal wastes that enter the groundwater are spatially significant problems which effect the groundwater quality. Policy for the control of non-point pollution is sparse. Farm management practices using economic instruments was mentioned above regarding run-off. Research into animal loadings is occurring at the Soil Science Department at Lincoln University. This is a source of pollution that is difficult to prevent given the landuse on the Plains. As Bradley (1992) states "the whole issue of non-point source pollution, particularly within our agricultural base in New Zealand is one I believe we yet have to come to grips with" (Bradley, 1992). Without a change in landuse practices it is not possible to prevent this pollution occurring. For grazed pastures, obvious solutions include reduction in stocking rate densities, use of crop-pasture rotations to keep the soil nitrogen in balance, frequent livestock transfers and reduction of clover content of pastures (Dillon *et al* 1989:354).

7.4 The National Response to Drinking Water Quality

New Zealand has four principal tools to assess the ability of water supply authorities to maintain a supply of safe wholesome water. These include; drinking water standards, grading of water supplies, monitoring the quality of drinking water, and surveillance.

The perceptions of water quality, demands by the public and what is expected of water body authorities especially on public systems helps to guide the standards of water quality in New Zealand. These standards are important because of the implications to public health.

Drinking Water Standards in New Zealand

In 1960 the former Board of Health adopted the World Health Organisation's (WHO) International Standards for Drinking Water as the criteria for assessing the quality of drinking water in New Zealand. Since then the Department of Health has used them for assessing the quality of wholesome drinking water. In 1978, following concern of member countries about likely health effects of trace levels or inorganic and organic substances in drinking water. The WHO convened Task Groups to review the standards. The result was new Guidelines for Drinking Water Quality. New Zealand's standards were developed in 1984 by the former Board of Health.

The objective of the standards given by the Board of Health, (1984) is that 'water for drinking and other domestic uses should be safe, palatable, and aesthetically pleasing....free from pathogenic organisms...and objectionable colour, odour, taste and turbidity" (Board of Health, 1984:1). The primary aim of the Drinking Water Standards for New Zealand is the "protection of public health" (Board of Health, 1984:1). Health defied by the WHO is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (Board of Health, 1984:1).

Since the 1984 guidelines were published many "new" chemicals have been introduced that can pose risks to human health if consumed. This is particularly the case with pesticides and organic chemicals which are now available. The current standards are out of date and recent public concern over drinking water quality particularly aluminium, disinfection by-products, Giardia, Cryptosporidium, fluoride and asbestos highlight this fact (Shaw, 1993). This led to a replacement of the 1984 standards for the 'Drinking Water Standards for New Zealand 1995'. "The Standards complement the modified grading criteria for public drinking supplies and form an integral part of the water grading process which determines how well a water supply meets the minimum requirement" (Ministry of Health, 1995).

The advantages of setting mandatory standards against guidelines is that it will be a statutory requirement to meet these standards. The requirement for water supply authorities to demonstrate that drinking water consistently meets the drinking water standards has not been rigorously pursued by public health agencies (Shaw, 1993). The current legislation allowing the implementation of standards and guidelines can be found in the Health Act 1956 and the Water Supply Regulations 1961.

Slater (1992) states that there are many scientific limitations to standards because of the uncertainties that exist, these are uncertainties associated with;

- the relationship between cause and effect,
- long term effects,
- effects being adverse or benign,
- adverse effects will be mitigated in all circumstances by applying the standards.

There are also disagreements relating to social aspects such as;

- the objective for which the environmental standard is sought,
- cost/benefit tradeoff is setting particular objectives
- acceptability of standards in light of scientific uncertainties,
- community acceptance and perception of risk.

(Slater, 1992)

Grading of water supplies was a tool first used in 1970. Until 1993 grading criteria was based on the nature and quality of the source water, the methods of water treatment, the characteristics of the reticulation and qualifications of the the staff employed at the treatment plant. (Prendergast, 1993). The quality of the product and the consistency with which quality is maintained played only a minor role in the grading. Regrading that is due every 5 years is 7 years overdue. The new grading system make the demonstration of a consistently good quality product necessary. (Prendergast, 1993).

Monitoring procedures are lacking in New Zealand. A 1989 survey on the effectiveness of disinfection indicated that at least 45% to 50% of water supply authorities do not monitor their chlorine dosage satisfactorily, 28% never test the bacteriological quality of the water before it enters the reticulation and another 30% test only 4 times a year (Taylor, 1993:5). Monitoring is the most ignored of all of the tools of drinking water quality. Data of water quality in an area is difficult to acquire. Databases are of limited supply and of dubious quality.

Taylor (1993) continues by saying "Of the six principle surveillance activities listed in the 1984 Standards as being carried out by the Department of Health, apart from the radiological surveillance programme operated by the National Radiation Laboratory, only one is still maintained by the Ministry" Once a monitoring system is established surveillance will involve the appropriateness of the system and ensuring there are national consistencies.

7.5 Groundwater Management

Groundwater pollution decision-making and environmental management must be accomplished in a holistic way, a way that is not only desirable but necessary under the RMA. Because of the nature of the groundwater resource in the WD, with its strong interrelationship with land, the two cannot be managed separately if a holistic approach to management is to be adopted. Therefore the cooperation between the regional and local authorities must be strong, and policy and decision-making consistent.

A strategy consistent with a holistic approach is managing the entire groundwater system and its interrelated parts. This approach to water resources issues ensures that land resources are considered conjunctively with water resources. A major problem is that of ownership and the history of the landuse and management. Because the District and Regional Councils do not own the land they only have indirect control.

Political will to take action is important. "Political will is the existence of a political climate which supports the development of a public sector response" (Canter, *et al,* 1988). To develop a political will there must be awareness, executive pressure, bureaucratic pressure and external pressure. With recognition of the extent of a problem, pressure for change by an executive officer, or within the agency, and public support, groundwater protection can become an important local objective.

Changing public attitudes to environmental pollution undoubtedly are of major political significance in pollution control. But attitudes themselves are very much a product of the scale and particularly the distribution of the nuisance.

> "The shift of public opinion against pollution has been most instrumental in determining the level of pollution abatement, because pollution control is, in the last resort a political judgement of balancing gains to the public health and general amenity against the costs of modifying or closing down the pollution activity"
>
> (O'Riordan, 1979:224).

As has been stated throughout the thesis groundwater must be protected primarily for the health and safety of the community. This includes the existing community and future generations. As the WD increases its population, it becomes more important to successfully manage the land and water resources. As stated above "the ability of the District to grow and prosper is first and foremost dependent on the quality of its groundwater" (WDC, 1993:10). Groundwater protection is therefore a District wide concern. The ability of land development proposals such as subdivisions to be successful depends on their ability to provide suitable sewage disposal, so as not to endanger the health of the existing community, and a potable water supply to protect the health of the new residents.

With the existence of regionally significant groundwater pollution it is important to establish management strategies that are in line with this. Scale problems are particularly acute when operationalising the concept; of protecting the entire groundwater system. Large scale protection schemes, that involve changes in landuse practices etcetera, break the mould of short term solutions to selective water quality problems. There is movement away from 'react and cure' towards the 'anticipate and prevent' approach.

Successful management begins with knowledge. An understanding of the hydrogeological system and how it will respond to imposed stresses is essential. Knowledge of all discharges both point and non-point source, water demands present and future, and the quality of the water is needed. An appreciation of the needs and perceptions of the community and the identification of priority areas is also essential.

While successful management is seen as the desirable outcome there are constraints facing the decision-maker, listed by O'Riordan and More (1969) as; physical, fiscal, policy, legal, administrative, ownership, quantification and perception (pg 572).

7.6 Summary

This chapter has discussed a variety of responses to groundwater pollution at a variety of scales from individual to national. Individual responses can be categorised as being reactive, while local authorities respond to groundwater pollution in a more preventative way. Because of the RMA and its emphasis on effects, it is now important to look at preventing, avoiding and mitigating adverse effects that can be caused because of pollution instead of treating the problem.

Motivations for responses and management strategies differ. An individual response strategy depends on the perception of water pollution (as discussed in chapter 6). The individual is interested in providing for the safety of the household, while the territorial authorities are responsible for the health and safety of the community and protecting the natural and physical environment, therefore solutions to groundwater pollution will be broader and more varied.

At the National level tools such as; drinking water standards, grading, monitoring and surveillance have been developed for maintaining drinking quality. These are proactive responses that in theory provide a framework for the safe supply of drinking water.

The importance of groundwater management in the WD, was discussed in its capacity to protect the water resource, so as a safe, potable water supply is available. Management is also important because of the role that the water resource plays in relation to growth of the District.

CHAPTER EIGHT

Conclusions

8.0 The Nature of the groundwater resource

This thesis set out to answer the four questions that were posed in chapter one. The first of these was to establish the nature of the groundwater resource, particularly in Mandeville. The thesis demonstrated how the groundwater resource in Canterbury is contained within glacial outwash and post-glacial alluvium plains. It is the geology of these plains that determines the routes and rates of the groundwater flow in the Canterbury region. The groundwater system is such a complex structure that its analysis, and the interpretation of information relating to it, must take these complexities into account. Similarly to a river groundwater will change course, alter its flows, and volumes. These changes will effect its capabilities to carry, disperse and dilute substances.

8.1 Groundwater Pollution in the field area

The second question posed was whether there is a groundwater pollution problem in the study area. Water quality results in the study areas showed variable results. The highest recorded count was 100 total coliforms per 100 ml of sample. Faecal coliforms, according to Sinton (L. Sinton, Microbiological Technician, Environmental Science & Research, 1994, *pers. comm.*), are often found in the shallow unconfined aquifers of Canterbury. This was the case in the field area.

The highest nitrate-nitrogen level was 9.8 g/m^3 at the Mandeville Sports Centre. Suggested causes for this are the existence of the rural residential subdivision upstream, or the fact that the test was taken before a heavy rainfall. Many wells in the study area averaged around 5.0 g/m^3. Water results that were below 4.0 g/m^3 tended to be from the zone by the Eyre River which is influenced by river recharge. This indicates a relationship between water quality and the recharge source.

Because of the time limitations and the associated difficulties in tracing pollutants, it was very difficult to interpret water quality results. Because of the restrictions and costs of undertaking water quality tests, there was a reliance on previous water tests. It can be seen from the results of these, that at certain times and places in the study area there is the occurrence of groundwater pollution. The pollution is not constant but fluctuates with meteorological factors, and with different farming techniques. Two wells located adjacent to each other but at different depths may have very different results. Shallow wells tend to be more susceptible to groundwater pollution.

Groundwater pollution is not confined to New Zealand. It is an international problem that faces both the developed and developing worlds. Das Gupta (1992), stated that in the 1980s in Sri Lanka 75% of wells tested were bacteriologically polluted. It is also estimated "that half the population in the OECD countries can only obtain clean water from treatment plants" (JRO, 1994:12).

The natural cycle of the hydrologic system involves the infiltration of water through the soil. The permeable nature of the material in the Canterbury Plains means infiltration of rainwater, irrigation is a predominant recharge to the groundwater system. It is this process that leads to pollution of the groundwater system. Well results from the study area and data from the Canterbury Regional Council, determine that it is rainfall recharged water results, that show the lowest water quality in comparison to river recharged wells (Smith, 1993b).

8.2 Groundwater quality perceptions

The third question relates to the perceptions of the interested parties in the groundwater resource, particularly at Mandeville. This thesis has contributed to the literature on perceptions, by highlighting the fact that groundwater pollution means different things to different people, it is surrounded by value judgements. Groundwater pollution is consistent with other hazards in that there is little acknowledgement of the risk by the individuals in the study area. While standards are used to assess groundwater quality, the majority of individuals are not aware of the 'scientific' quality of their water, or the standards by which they are assessed. On the basis of past perceptions of high water quality 55% of the individuals in the rural sectors of Mandeville perceive their water quality to be 'excellent' while no rural residential occupants thought their water was 'excellent'. This result is based on the fact that the rural residential residents have a reticulated chlorinated water system. Unlike the rural occupants, the quality is based on the smell, taste, and colour of the water.

The perceptions of the 'experts' from the WDC, CRC and ESR differ in that they feel the quality of the water in the Mandeville area is not as potable as it should be for a drinking water source. Answers were based on comparative studies, and the opinions of the EHOs in the Waimakariri District.

Perceptions of different interested parties are an important part of decision-making. An understanding of the perceptions of other interested parties is important for conflict resolution. Two-way communication is important for all parties. Perceptions are also important because of how an individual or organisation will respond or choose not to respond to groundwater pollution.

8.3 Management Options

The fourth question posed in the thesis relates to the management options that are used at present and options that can be used in the future. There are a variety of responses to groundwater pollution, at a variety of scales from individual to national. Individual responses can be categorised as being reactive, while local authorities respond to groundwater pollution in a more preventative way. Because of the RMA and its emphasis on effects, it is now important to look at preventing, avoiding pollution instead of treating the problem.

A monitoring system could be established in the District in areas where bacteria counts and nitrates are predominant. If the quality of water is found to be deteriorating options must be investigated to prevent the pollution of wells, both private and public. Detection of the source of pollution is paramount. Following that solutions must be found to prevent or mitigate the effects of the pollution. If this is not a viable option then an alternative source could be found or the water must be treated.

Groundwater protection is not a perspicuous undertaking. It requires extensive data collection and evaluation. The only efficient way to approach the topic is to build on existing information to the greatest extent possible and to target additional data collection and evaluation activities. Public participation and education are important components of any planning effort and from the beginning.

The long term success of establishing a groundwater protection programme can be best evaluated by the lack of pollution threats to public and private wells. With preventative techniques the absence of problems is an accurate measure of success, instead of identifying pollution through monitoring and responding to it. (Page, 1987:155). It is important to consider the implications of these findings for rural subdivision.

Implications for rural subdivision

How does the quality of the groundwater (or perception of the quality) influence the demand and supply of land for rural residential purposes? If the land developer can prove that there are no adverse effects on the environment from this form of landuse then there should be no reason to prevent such development. At present, with a lack of planning policy in relation to rural residential policy and how it should be managed, development is occurring in a piecemeal fashion. There are a variety of options that can be adopted by Councils in regard to the development of rural residential areas. These include; piecemeal development, council initiated development and cooperative development.

Piecemeal development is where individual landowners develop blocks and provide for water supplies and sewerage disposal. This development is accepting the philosophy of the RMA as regards the ability of individual property owners to do whatever they like on there land, provided there are no detrimental affects on the neighbouring properties or the environment. It is also in line with the mentality of the Fourth Labour Government and the successive National Government in that the government should have a hands-off approach, with the mechanisms of the free-market being prevalent. The supply of essential services should not be a task for the DC, but should be tendered out to the best contractor. It should be necessary to establish maintenance contracts for sewerage disposal and water supplies. By monitoring these services the Council can ensure that services are adequately maintained.

Council initiated development is an option where the Council allows a certain amount of rural residential zones in an area. The DC would be actively involved in the planning and installation of services. This would provide well defined water supply areas and reticulated sewerage system areas. The site would have single water treatment and sewerage treatment points. The role of active planning is a familiar method to DC's, which has to a certain extent been superseded by the philosophies of the RMA, in that development can occur anywhere (in theory) as long as there are no adverse effects on the environment and, now (again in theory) market forces will determine where development will occur.

Cooperative development relies on individual developers working together to provide services to minimise capital costs and maximise the utilisation of available land. This however is unlikely because developments rarely occur at the same time and because of the competitive nature of land development (sections on the market at the same time would decrease the price of the land). As Leslie Woudberg stated in relation to planning and management "it will be another 10 -15 years before we see a change in way things are done" (L. Woudberg, Planner, WDC, 1994, *pers. comm.*). It looks likely that there will be a continuation of Council initiated developments.

Rural residential developments are set within a legislative framework that does not allow for negligent disposal of effluent. There should be no deterioration of the groundwater environment via such developments. Chlorination of water supplies that are not potable, while being an accepted practice in the eyes of the DC are not so acceptable to the residents. But if the Council accepts the common law maxim of "buyer beware", then the aesthetic quality of water should not be a limit to development of the land for rural residential subdivision.

8.4 Conclusion

This thesis has shown that the reality of groundwater pollution is that it is a variable hazard. Pollution changes its location and its concentration in response to a variety of climatological factors, flow patterns, and landuse practices. The complexities of these variables means that pollution detected is only an indication of what is occurring at certain places at certain points of time.

Overall it can be said that while a district grows and develops it must realise that it is limited by its natural resources. Growth in a district while providing economic benefits, may have detrimental impacts on the environment and hence the community. Further study in the area of rural subdivision and its impact on the groundwater system, would benefit communities and territorial authorities.

While new rural residential subdivisions are subject to discharge standards, established subdivisions with on-site individual septic tanks maybe substantial polluters to the groundwater system. This issue requires resolution for the effective ongoing development of rural subdivisions.

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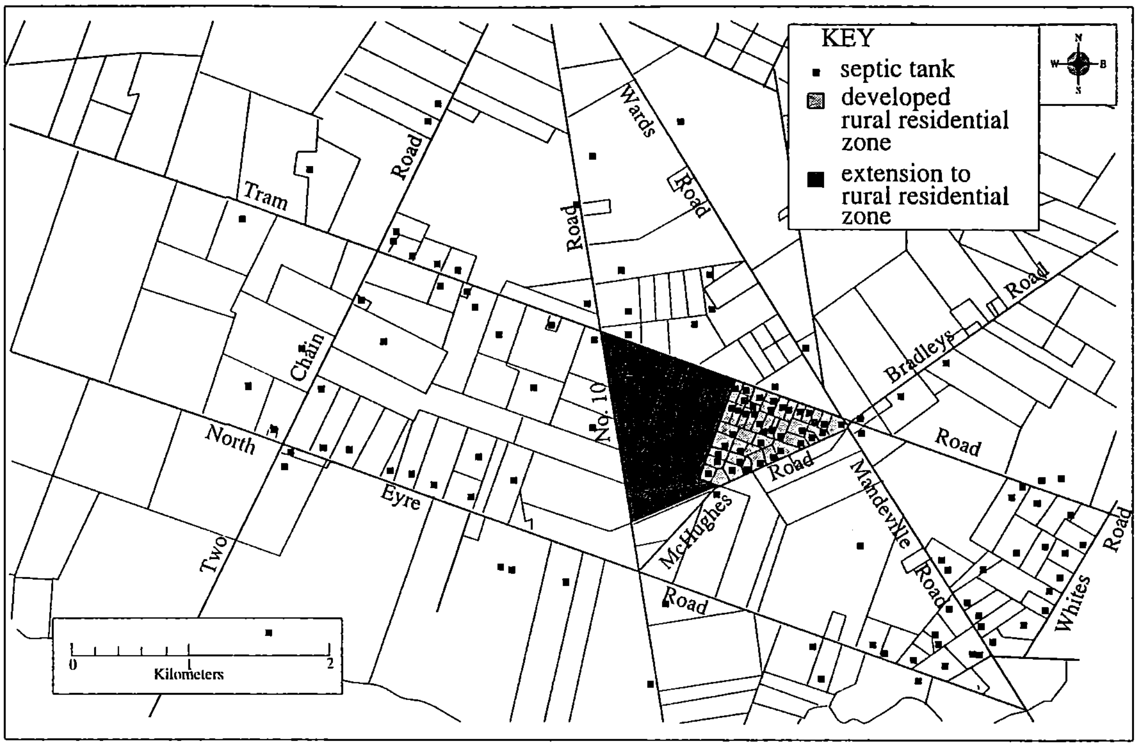
Appendix 1: Locations of residencies and the newly assigned rural residential zone.



Appendix 2: WDC Survey

WAIMAKARIRI
DISTRICT COUNCIL

Ground Water Study

Wells and Septic Tanks

UPI ____ / ____ Number / Road No.

Name ____

Phone No. 0 3 ____

Parcel Description Lot ____ DP. ____

or ____

WELLS

Connection to domestic supply Yes | No

CRC Well No. ____

Diameter ____ mm Depth ____ m

Domestic Yes | No

No. of Dwellings ____

Irrigation Type ____

Usage ____ m^3 / day

Power Bill ____ $ / month

SEPTIC TANKS

Treatment System ____

No. of cells ____ Depth ____ m

Disposal Soak Hole / Old Field Tile ☐ Pumped Yes ☐ Trench Filter Lines ☐

Spray Irrigation ☐ EVT ☐ Other ____ ☐

No. of People ____

Waste Disposal Units ____

Performance 1 2 3 4 5 6 7 8 9 10

Comments ____

Last Cleaned ____ How ____

OTHER WASTE DISCHARGE

Where ____

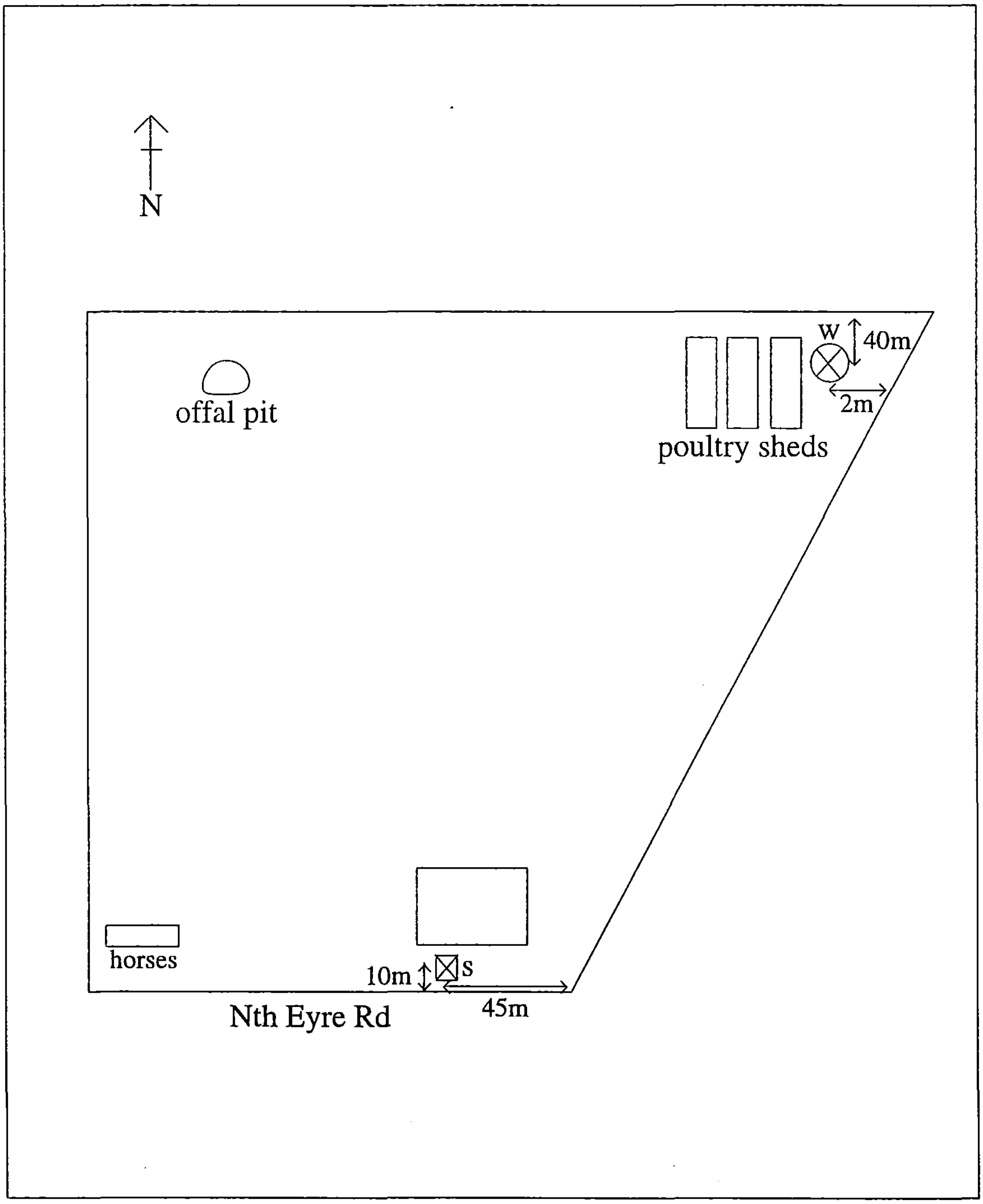
How much ____ m^3 / day

Type		No.	Disposal Method
	Pigs		
	Fowls		
	Cowshed		
	Commercial		
	Other		

WELLDATA.PMS

Locality Plan overleaf

Example of Locality Plan on rear side of survey



Appendix 3: Survey on Perceptions of Water Quality in the field area.

1) When you think of your underground water supply, what is the first word that comes to mind?................................ (If pollution mentioned ask Q.1a) otherwise Q.2.

1a) In your opinion what can be done to correct the water pollution problem?
....

2) How do you rate the condition of your underground water supply?
(when 1= exellent and 5 = very poor) 1 2 3 4 5

3) Who or what do you think is the biggest consumer of the underground water?
residents [ ] residents combined [ ] irrigation [ ] drinking water animals [ ]
other [ ] (specify)......................

4) Who or what do you think is the biggest polluter of the underground water?
human effluent [ ] animal effluent [ ] animal spraying effluent [ ] agricultural [ ]
sprays [ ] other [ ] (specify)......................

5) Who do you think should be responsible for your water supply;
installation? [ ] self [ ] developers [ ] WDC [ ] CRC [ ] independent body [ ]
monitoring? [ ] self [ ] developers [ ] WDC [ ] CRC [ ] independent body [ ]

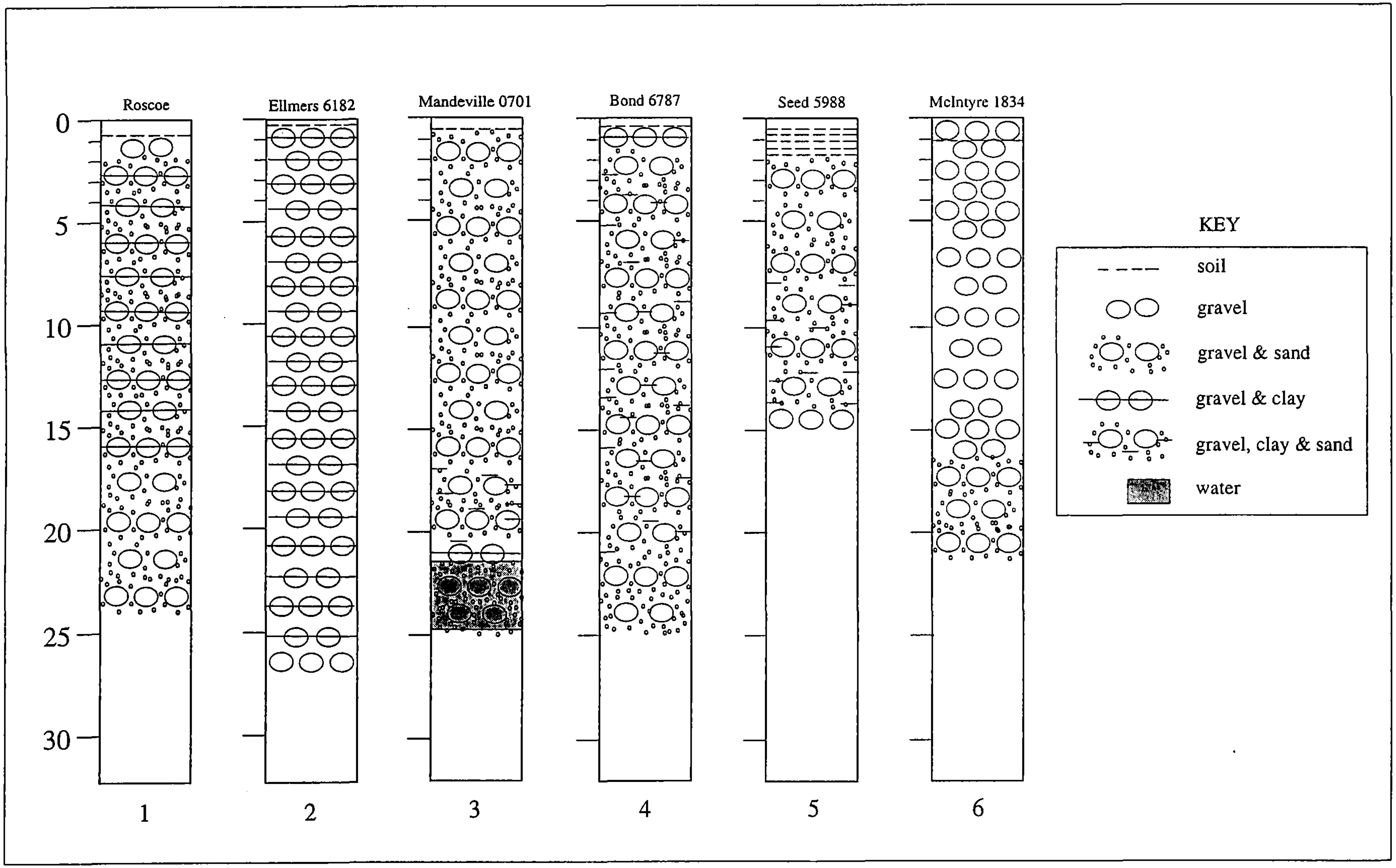
6) Would you rather be on - your own well? [ ]
- community system? [ ]
why?..

STATISTICAL QUESTIONS
7) Gender M F

8) Occupation Interviewee................................
Main Occupation................................

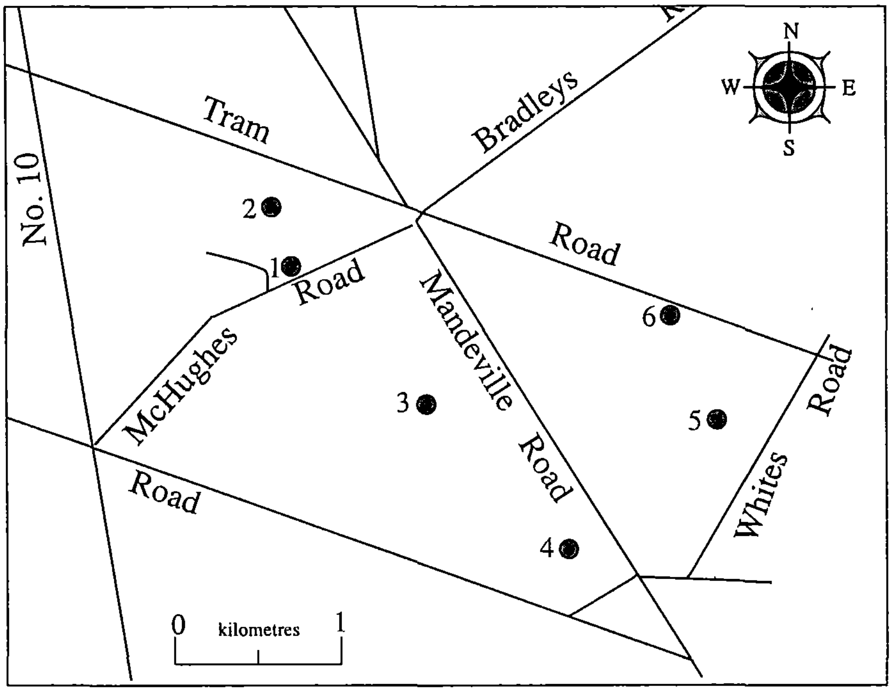
9) Age................

Name..................................
Property Number 21710.............
Well Number M35..............

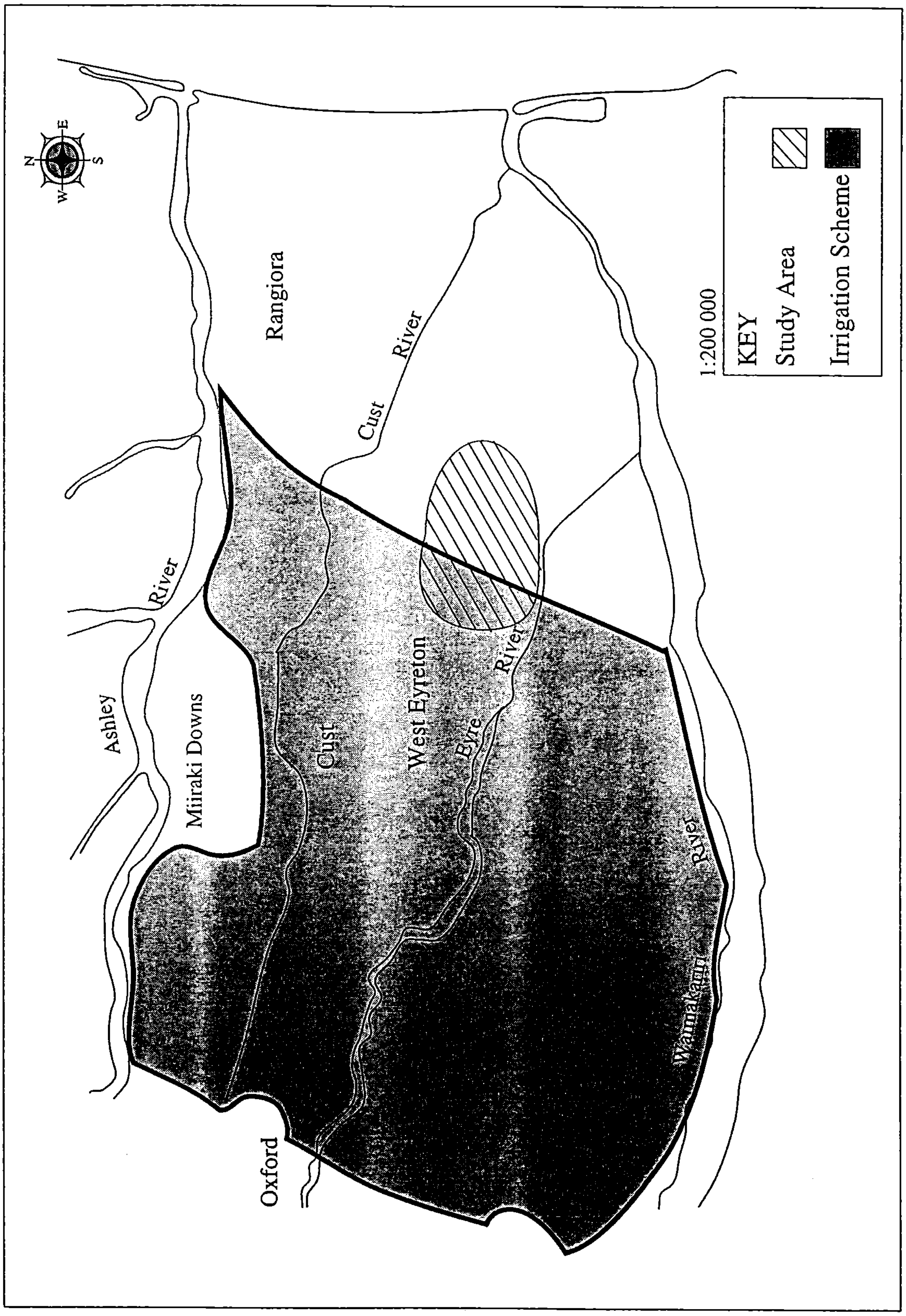


Appendix 4: Well logs located in the field area demonstrating the variability of geology.

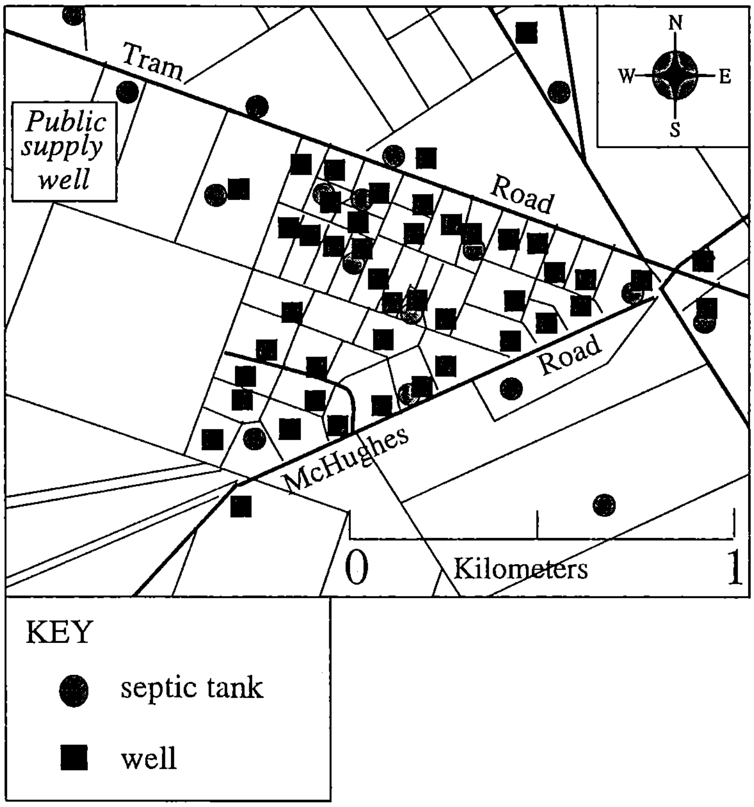
Appendix 5: Location of well logs from Appendix 4.



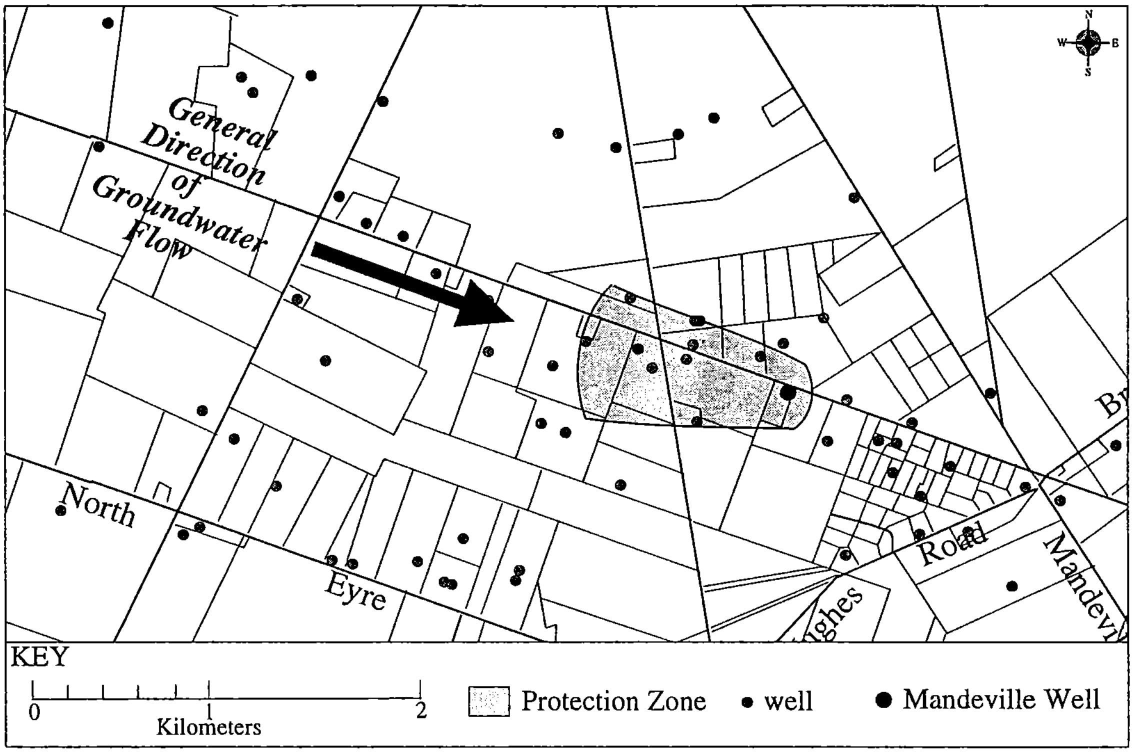
Appendix 6: Extent of Irrigation scheme and location of field area.



Appendix 7: Location of wells and septic tanks in rural residential subdivision



Appendix 8: Protection Zone located around the Public Supply well at Mandeville



Appendix 9: Relevant parts of Section 31. RMA, Functions of territorial authorities under this Act.

"Every territorial authority shall have the following functions for the purpose of giving effect to this Act in its district:

(a) The establishment, implementation, and review of objectives, policies, and, methods to achieve integrated management of the effects of the use, development, or protection of land and associated natural and physical reources of the district:

(b) The control of any actual or potential effects of the use, development, or protection of land, including the implementation of rules for the avoidance or mitigation of natural hazards, and the prevention and mitigation of any adverse effects of the storage, use, disposal, or transportation of hazardous substances:

(c) The control of subdivision of land:

(e) The control of any actual or potential effects of activities in relation to the surface of water in rivers and lakes:"

Appendix 10: Section 406 RMA 'Grounds of Refusal of Subdivision consent -'

"Notwithstanding anything to the contrary in PartsVI or X, a territorial authority-

(a) Shall not grant a subdivision consent if tit considers that either-

(i) The land in respect of which the subdivision is proposed is not suitable; or

(ii) The proposed subdivision would not be in the public interest:

(b) May refuse to grant a subdivision consent if the case of any allotment in respect of which a subdivision consent is sought, adequate provision has not been made or is not practicable-

(i) For stormwater drainage; or

(ii) For the disposal of sewage; or

(iii) Except in he case of any allotment to be used solely or principally for rural purposes, for the supply of water or electricity"

Appendix 11: Relevant parts of Section 30, 'Functions of regional councils under this Act' to groundwater pollution.

(a) The establishment, implementation, and review of objectives, policies, and, methods to achieve integrated management of the natural and physical resources of the region:

(b) The preparation of objectives and policies in relation to any actual or potential effects of the use, development, or protection of land which are of regional significance:

"(c) The control of the use of land for the purpose of-

(ii) The maintenance and enhancement of the quality of water in water bodies and coastal water:

(iii) The maintenance of the quantity of water in water bodies and coastal water:

(iv) The avoidance or mitigation of natural hazards:

(e) The control of the taking, use, damming, and the diversion of water, and the control of the quantity, level, and flow of water in any water body, including-

(i) The setting of any maximum or minimum levels or flows of water:

(ii) The control of the range, or the rate of change, of levels or flows of water:

(f) The control of discharges of contaminants into or onto land. air, or water and discharges of water into water:"